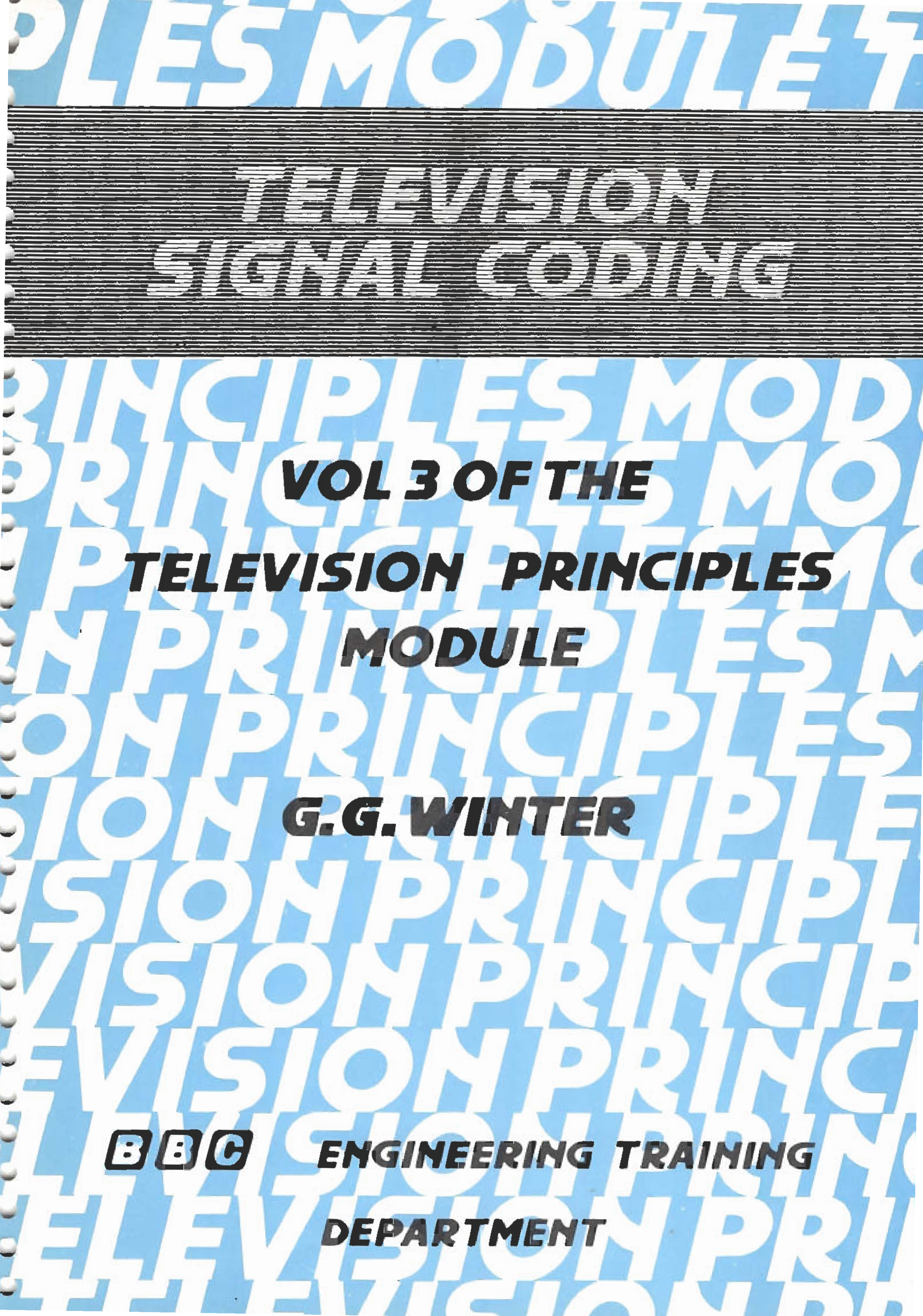

TELEVISION SIGNAL CODING

VOL 3 OF THE TELEVISION PRINCIPLES MODULE

G.G. WINTER

BBC ENGINEERING TRAINING DEPARTMENT

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MODULE STRUCTURE

The Television Principles Module consists of three separate, but related, packages which should be undertaken in sequence, as indicated below:

TELEVISION FUNDAMENTALS

This package deals with the basic principles of television and develops the requirements of a basic monochrome (black and white) system. The television signal is constructed step by step and some particular circuit techniques are considered. Emphasis is placed on describing the U.K. 625 line system.

COLOUR TELEVISION PRINCIPLES

This package studies Colorimetry and describes how its principles can be used, together with the monochrome television system, to provide a Basic Colour Television System.

TELEVISION SIGNAL CODING

This package develops further the basic colour television system into the final system. The NTSC system is considered first and then the British PAL system. Reference is also made to the SECAM system.

AIMS OF THE PACKAGE

The broad aims of this package are:-

1. To explain the principles of Suppressed Carrier Modulation.
2. To examine in detail the characteristics of Suppressed Carrier Modulation, using phasors to analyse the chrominance component of Colour Bars.
3. To identify the characteristics and problems associated with the composite coded video signal.
4. To establish the types of distortions which affect the coded video signal.
5. To highlight the principles of the NTSC, SECAM and PAL systems of coding.
6. To analyse the detailed operation of the PAL system.

PACKAGE STRUCTURE

This package consists of two written units. This unit contains the theory associated with the coding of a colour television system, and the other unit contains details of various practical demonstrations for you to undertake during your study.

The theory unit is divided into seven sections. The first six sections cover the subject aims as detailed at the top of this page, and the final section contains revision notes on the whole package.

STUDY GUIDE

This package is self-paced, but as a guide you should expect to complete it in about three half-day periods.

As you read through the text, you will find reference to a number of practical investigations for you to undertake, and a number of questions for you to answer. When a concept is introduced for the first time it is referenced by a 'keyword' shown in bold type in the right-hand margin. For revision purposes a list of these keywords is given in the Index at the end of the package.

When a practical demonstration or investigation is necessary, the theory unit will direct you to the appropriate activity in the practical unit. You should then leave the theory unit and undertake the practical activity as instructed. However, if the practical equipment is not available at the time, you may continue with the theory unit, but the practical should be undertaken as soon as possible.

Throughout the package you will find a number of questions to answer, or waveforms to draw. Answers to questions in the Theory Unit should be written on a separate sheet of paper which your tutor can then use to assess your progress through the package. Spaces will be found within the practical unit for you to answer some of the questions or draw the waveforms as required. If you experience difficulty in answering any of the questions you should consult your tutor.

At the end of the theory unit there is a summary of the work that has been covered. This consists of brief notes, and is intended for revision use only after you have completed the package.

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SECTION 1

SUPPRESSED CARRIER AMPLITUDE MODULATION

1.1 CHOICE OF MODULATION TECHNIQUE

If normal amplitude modulation were used for the colour difference signals then at all times, even when the modulating signal was zero, there would be a constant level of carrier present. On a monochrome display, any brightness variation caused by this carrier would be noticeable on all parts of the picture.

Suppressed-carrier amplitude modulation has the advantage that the modulator output is zero when *no* information being carried, consequently there is *no* interference on the monochrome display. As an extra bonus, the amplitude of the modulator output increases with the amplitude of the modulating signal. When the colour difference signals are small, as in normal picture content, the modulator output is also small, giving reduced interference on average pictures compared to a NORMAL a.m. signal.

Normal a.m.

1.2 AMPLITUDE AND SPECTRUM COMPARISON OF AMPLITUDE MODULATION AND DOUBLE SIDEBAND SUPPRESSED CARRIER

Using a sine wave modulation input we can compare the spectral content and amplitude of the modulator output for both normal a.m. and suppressed-carrier a.m.

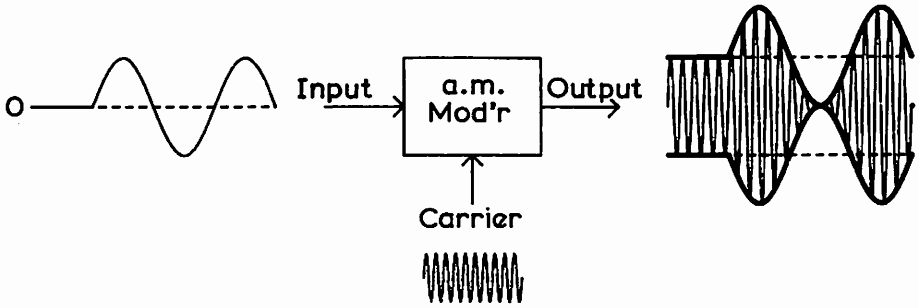


Figure 1.1 Normal a.m. carrying 0% and 100% Modulation

In figure 1.1 the first half of the output waveform shows that, for normal a.m., only carrier is present when there is no modulating signal. The second half of the waveform shows that a sine wave input with the same amplitude as the carrier gives 100% modulation and causes the modulated output signal to vary from twice carrier amplitude to zero during one modulation cycle.

The phasor and spectral representations for 100% modulation, for normal a.m., are given below.

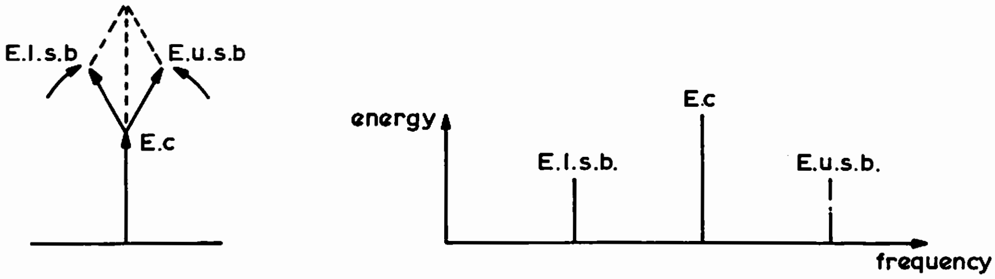


Figure 1.2 Phasor and Spectral Representations for 100% a.m. Modulation

Suppressed Carrier a.m.

The same amplitude of modulating signal, when carried by SUPPRESSED CARRIER modulation, has the phasor and spectral content shown in figure 1.3 below.

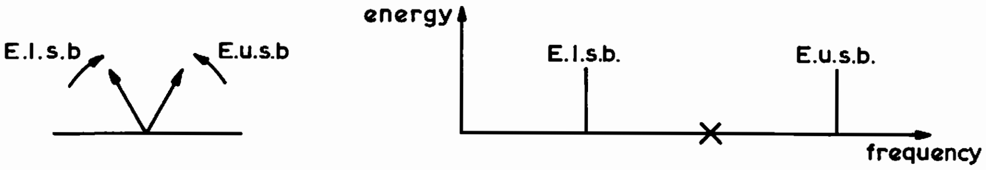


Figure 1.3 Phasor and Spectral Representations for Suppressed Carrier Modulation

If the input signal shown in figure 1.1 is now put into a suppressed carrier modulator, the modulated output is as shown in figure 1.4.

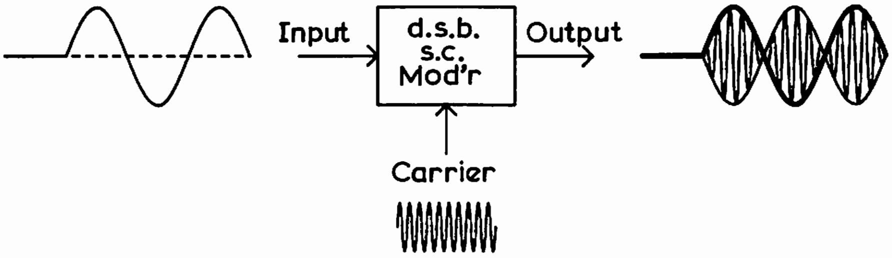


Figure 1.4 Suppressed Carrier Transmission of a Sine Wave

The same level of modulation is carried with an output waveform amplitude half that of normal a.m., reducing interference levels on monochrome displays even further for the same amplitude of information (colour difference signals) carried.

If the waveform of the suppressed carrier a.m. signal is examined closely it can be seen that the instantaneous peak-to-peak amplitude of the waveform is directly (×2) proportional to the instantaneous value of the modulating signal. It follows from this that no carrier is present for zero modulating signals.

As an aside, a suppressed carrier modulator *could* be made using a normal amplitude modulator, producing carrier + sidebands, and then cancelling out the carrier component by adding a fixed amplitude of neat carrier in antiphase as shown in figure 1.5.

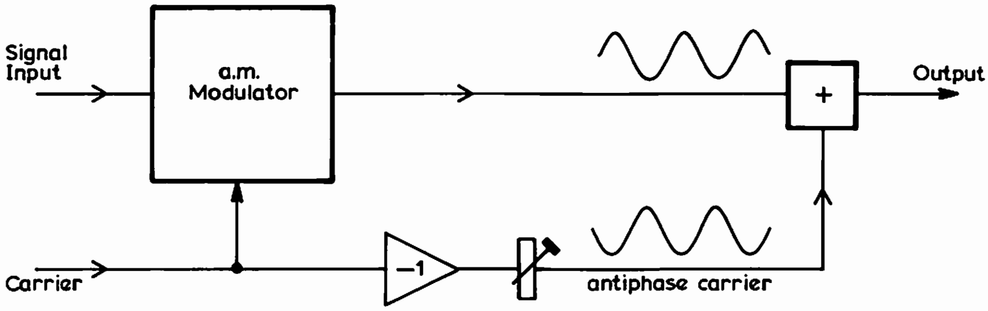


Figure 1.5 Crude Suppressed Carrier Modulator

Examine the case when the modulating signal is zero. The a.m. modulator outputs carrier only, which is 'balanced' out by the correct amplitude of anti-phase carrier. This is how the modulator may be set-up. This technique produced what was called a 'BALANCED MODULATOR'. The *name* has stuck for any suppressed carrier modulator, even though modern circuitry does not use this trick.

Balanced Modulator

1.3 SUPPRESSED CARRIER MODULATION USING COLOUR DIFFERENCE SIGNALS AS MODULATING SIGNALS

The examples shown so far are for a single-frequency sine wave modulating signal. Colour difference signals, however, are television (video) waveforms which have a d.c. component and extend to a bandwidth of 1.3 MHz. When this complex waveform is used with suppressed carrier modulation the spectral components cover the range shown in figure 1.6.

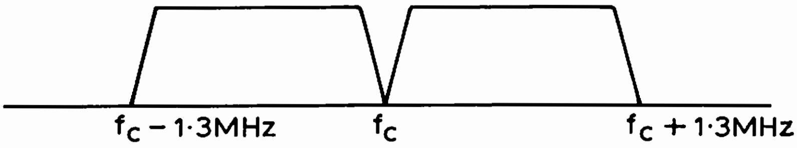


Figure 1.6 Spectral Components of Modulated Colour Difference Signals

Note that a suppressed carrier modulator gives no output with zero modulating input; but gives a carrier component with a zero-frequency (d.c.) modulating signal.

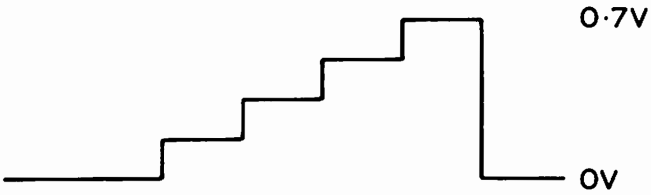
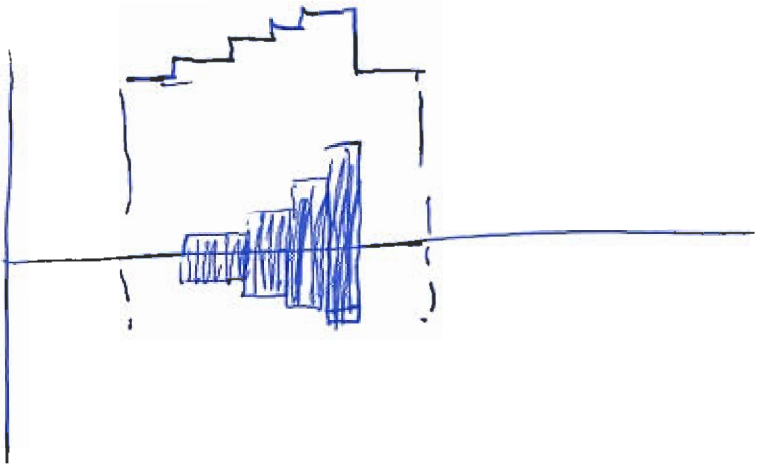
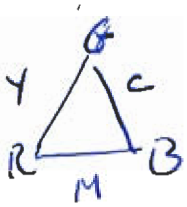


Figure 1.7 A Typical Colour Difference Signal

Draw the output waveform that you would expect from a suppressed carrier modulator which is fed with the waveform shown in figure 1.7 as its modulating signal input. Show about two cycles of sub-carrier for each step.





1.4 PRACTICAL VALUES OF (R – Y) AND (B – Y)

You have now established what the subcarrier waveform should look like for a colour difference signal, which extends from 0.7 volts to zero in four steps. But what is the range of practical values of (R – Y) and (B – Y) that we are likely to encounter?

To assess the requirements of the modulators, we first have to establish what input levels they will need to handle. The most extreme cases possible are those of the three 100% saturated primary colours (red, green and blue), the three complementary colours (yellow, cyan and magenta) together with black and peak-white.

Complete the table of values of colour difference signals shown below. Use the established formula $Y = 0.3R + 0.59G + 0.11B$ and work in % units, i.e. as the colours are 100% amplitude and 100% saturated, the values of R, G and B will either be 100 or 0. If you are at all doubtful about this, attempt the question on a separate piece of paper and ask your supervisor to check your results before copying them into the table below.

Colour	R	G	B	Y	R-Y	B-Y
White	100	100	100	100	0	0
Yellow	100 30%	100 59%	0 0%	89	11	-89
Cyan	0 0%	100 59%	100 11%	70	-70	30
Green	0 0%	100 59%	0 0%	59	-59	-59
Magenta	100 30%	0 0%	100 11%	41	59	59
Red	100 30%	0 0%	0 0%	30	70	-70
Blue	0 0%	0 0%	100 11%	11	-11	89
Black	0 0%	0 0%	0 0%	0	0	0

The main points to note from this table are:-

(a) With the given order of colours, the value of the Y signal decreases in steps from 100 to 0%.

(b) The values of R, G and B for the colours in the order given form a pattern.

(c) The amplitude of the colour difference signals is zero for monochrome (black and white). Check that this is true for a grey signal.
e.g. R = G = B = 50%

(d) The amplitude range of the colour difference signals varies from −70% to +70% for (R − Y), and from −89% to +89% for (B − Y).

If the colours described in the table are transmitted sequentially over one active line period, draw on a sheet of graph paper the waveforms which would result for the Y and colour-difference signals.

1.5 THE MODULATED WAVEFORM

The colour difference signals can have positive or negative values. Suppressed carrier modulation has only been considered for positive values of the modulating signals so far. What happens if the signal is negative? In a practical suppressed carrier modulator a phase inversion (180° phase shift) takes place.

d.s.b.s.c. Modulation

The two main characteristics of double side-band suppressed carrier MODULATION that are applicable to the coding process are:-

(a) The amplitude of the envelope is directly proportional to the amplitude of the modulating signal.

(b) The phase of the modulated signal is dependent on the polarity of the modulating signal.

1.6 METHODS OF MODULATION

Switching Modulator

The MODULATOR can be considered as a SWITCH in which the alternate positive and negative half cycles of the carrier switch the modulating signal between its normal and inverted values. A simplified block diagram of this type of modulator is shown in figure 1.8 and its associated waveforms are shown in figure 1.9.

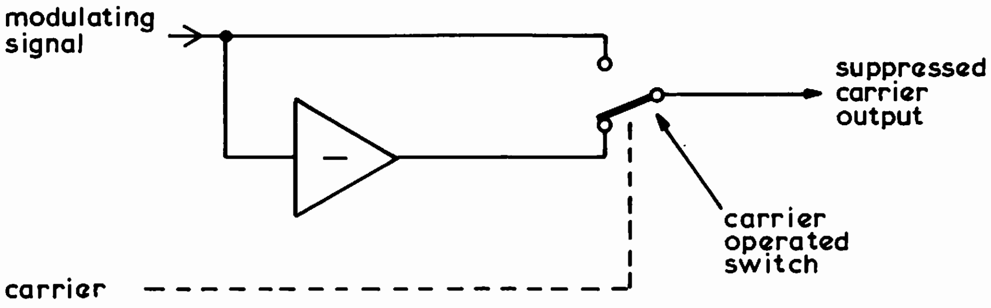


Figure 1.8 Principle of Operation of a Suppressed Carrier Modulator

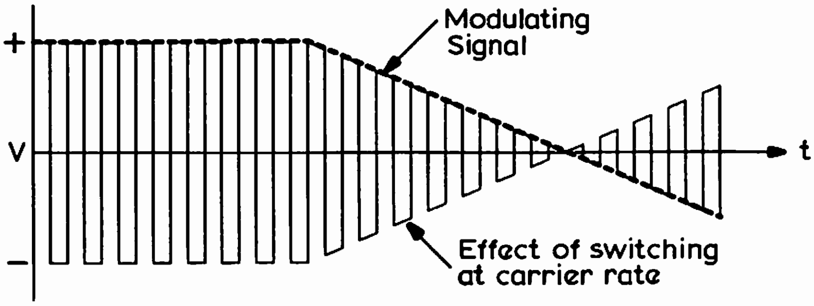


Figure 1.9 Waveform of a Switching type Modulator

This type of modulator displays the two characteristics established in sub-section 1.5. Passing the output of the switch through a low-pass filter removes the harmonic components (in practice, mainly the second and third harmonics) and restores the waveform to a sine wave. The modified block schematic is shown in figure 1.10, and its associated waveforms in figure 1.11.

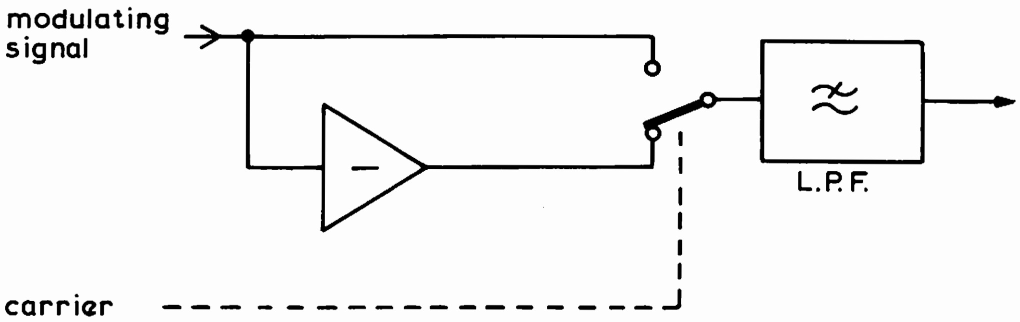


Figure 1.10. Suppressed Carrier Modulator with a Filter

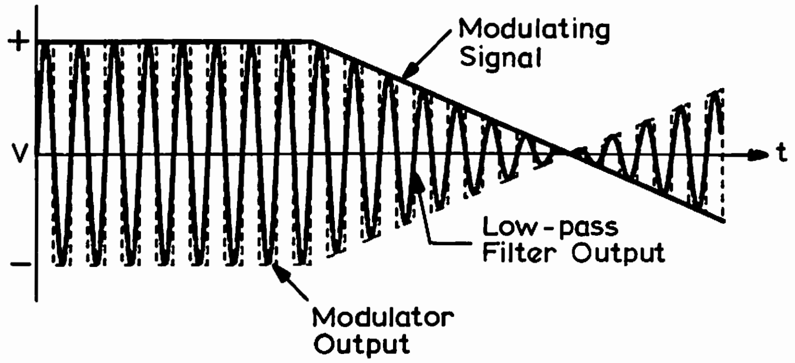


Figure 1.11 Output Waveform of Suppressed Carrier Modulator with Filter

Note that for a steady state d.c. input to the modulator the filtered output will be a sine wave at the carrier frequency.

1.7 A PRACTICAL SUPPRESSED CARRIER MODULATOR

Practical Modulator

Early modulators used the Ring Modulator principle in which a ring of four diodes was switched to give either normal or inverted signal transmission. A PRACTICAL suppressed-carrier MODULATOR may be constructed using four transistors as a two-pole two-way switch, and is shown simplified without bias circuitry in figure 1.12.

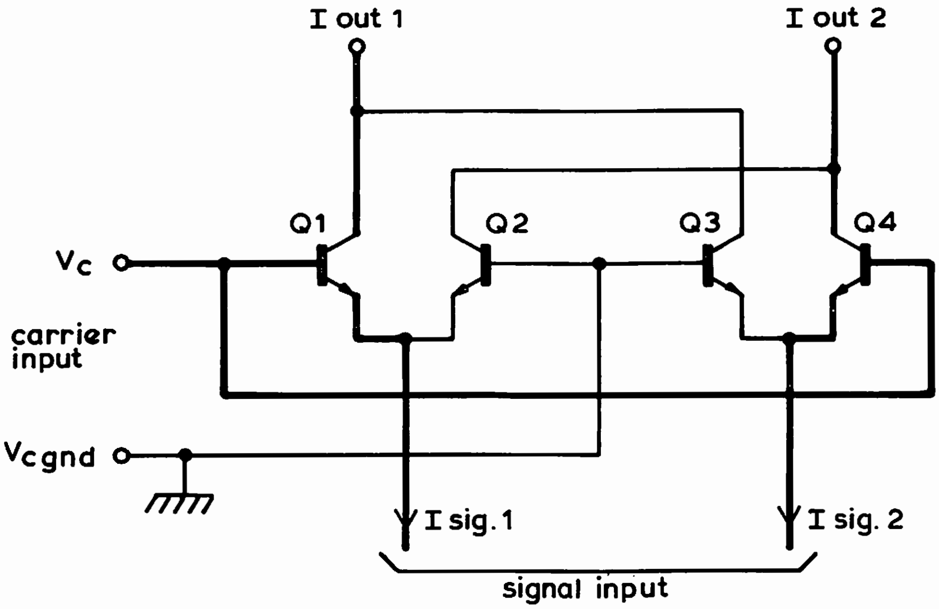


Figure 1.12. A Simplified Suppressed Carrier Modulator Circuit

Vc is the carrier input. When it is positive with respect to Vc ground, the two outer transistors (Q1 and Q4) conduct and connect I sig 1 to I out 1, and I sig 2 to I out 2. When Vc is negative with respect to Vc ground, the inner transistors Q2 and Q3 conduct to exchange the signal currents routed to the output transistors.

If the two signal currents are identical when the changeover takes place, no voltage change can occur in a load resistor connected to one of the outputs. If, however, the values of the two signal currents are made progressively different, than an increasing voltage difference will appear across the load resistor as the switch is operated, i.e. at carrier frequency.

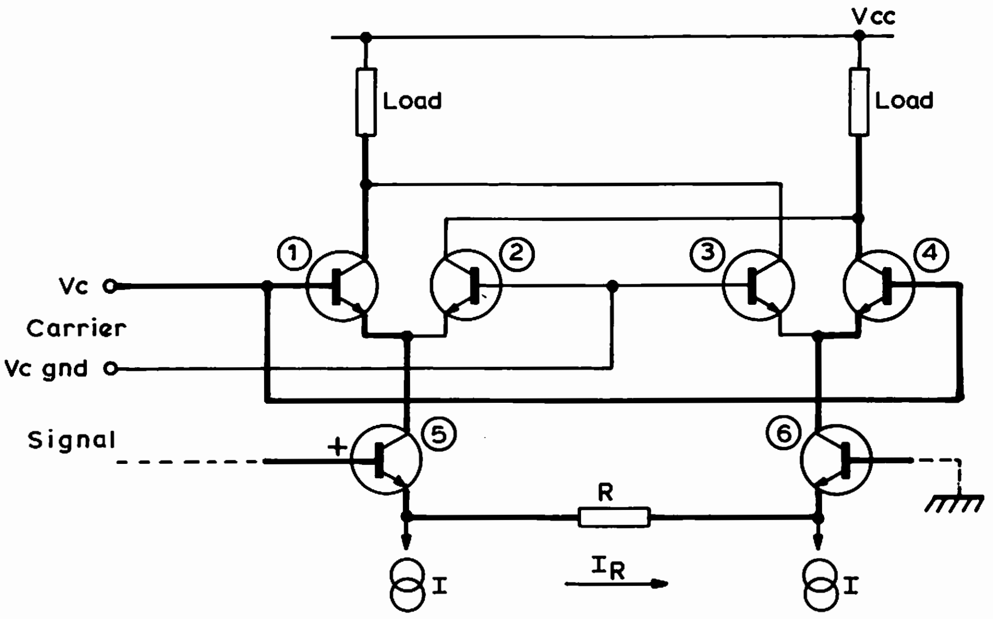


Figure 1.13 Theoretical Circuit for Suppressed Carrier Modulator

Two equal current sinks are used. Transistors Q5 and Q6 unbalance the load currents by cross-coupling a current, IR, via emitter resistor R. As a result current I - IR flows through transistor Q6 and current I + IR flows through transistor Q5. The value of cross-coupling resistor R can be varied to alter the cross-coupling gain and hence the gain of the modulator.

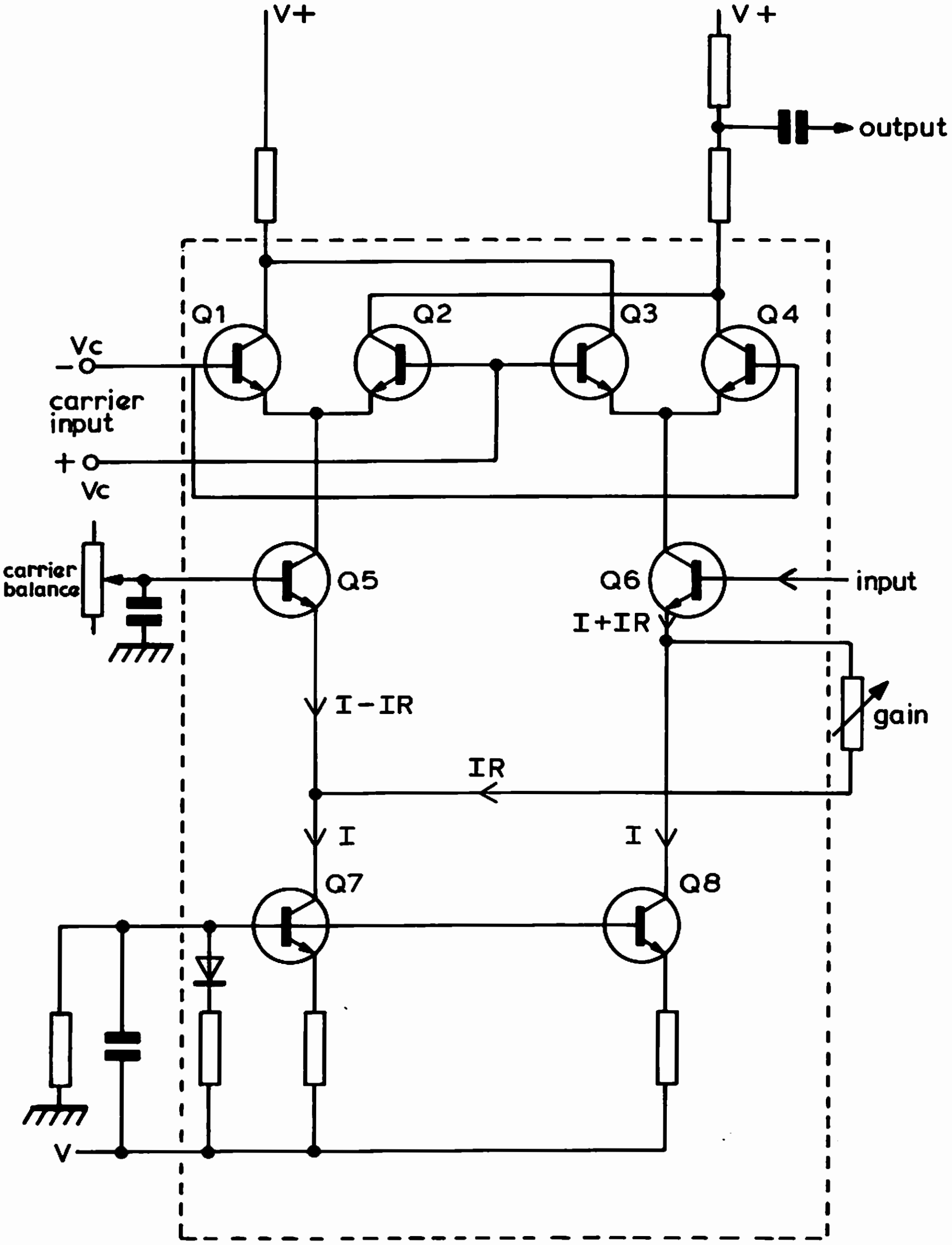


Figure 1.14 A Practical Circuit for a Suppressed Carrier Modulator

The final practical circuit is shown in figure 1.14 where Q7 and Q8 are the current sources. In modern practice the circuit within the heavy broken line is contained on a single integrated circuit. A MC1596 (1496) is a typical example.

1.8 DEMODULATION

Demodulation is the reverse of modulation. Modulation was achieved by alternately switching the modulating signal between its normal and inverted states, using the carrier as a switch. If the same carrier is used to switch the inverted parts of the modulating signal back to normal the original modulating signal can be reconstituted. If no subsequent filtering takes place, the process is as shown in figure 1.15. Practical waveforms are shown in figure 1.6.

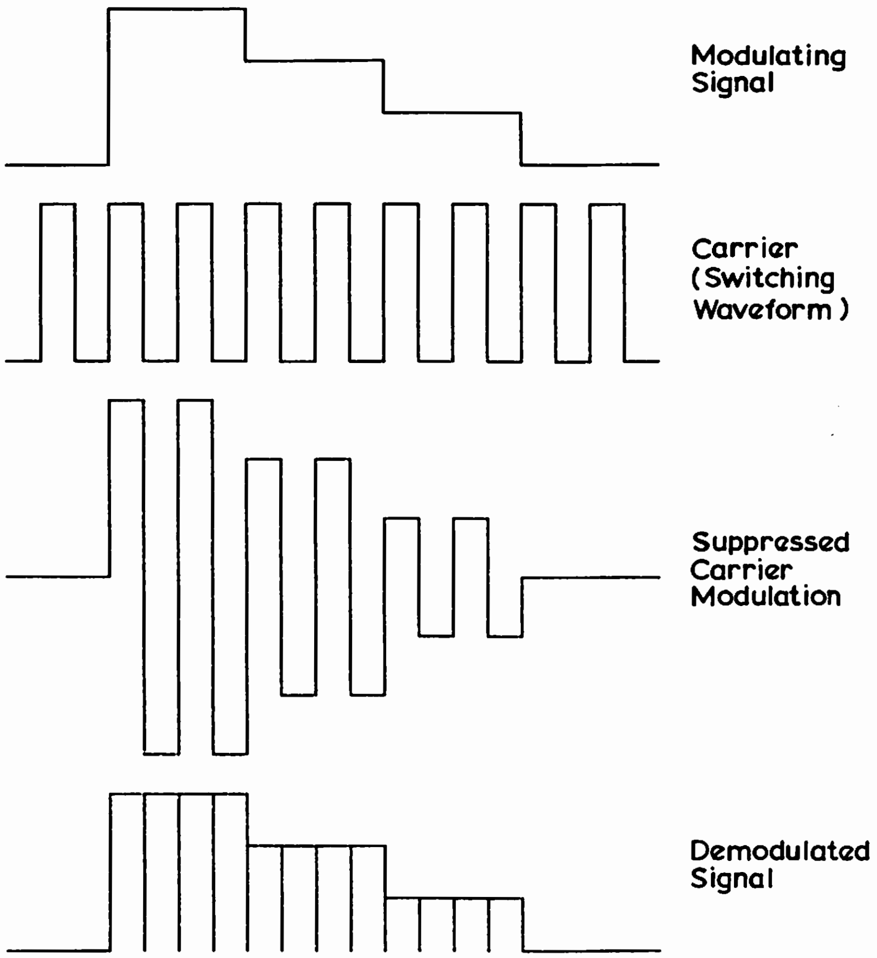


Figure 1.15. Suppressed Carrier Modulation and Demodulation

Suppressed Carrier Demodulation

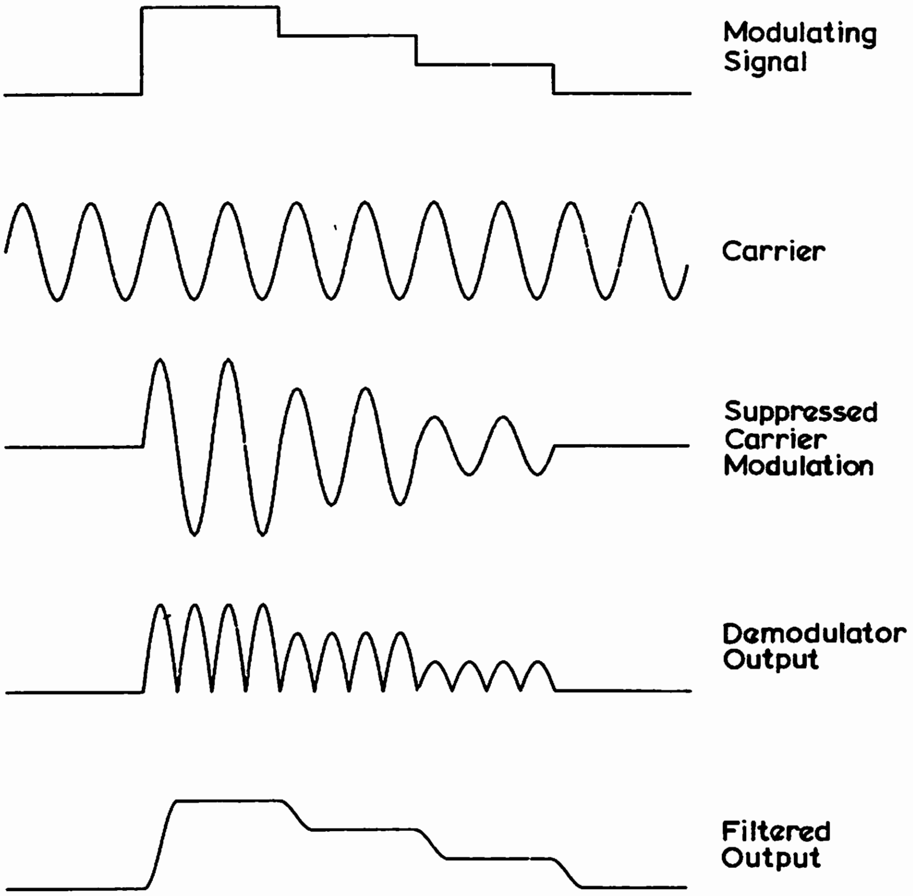


Figure 1.16. Practical Modulator and Demodulator Waveforms

This example has assumed only positive values of modulating signal. Colour difference signals, however, may be negative.

For the modulating signal shown in figure 1.17 draw the waveforms that you would expect:-

(a) At the output of the modulator (after filtering),

(b) At the output of the demodulator (before filtering);

(c) At the output of the demodulator (after filtering);

(d) At the output of the demodulator, both before and after filtering, if the phase of demodulating subcarrier is shifted by 180°

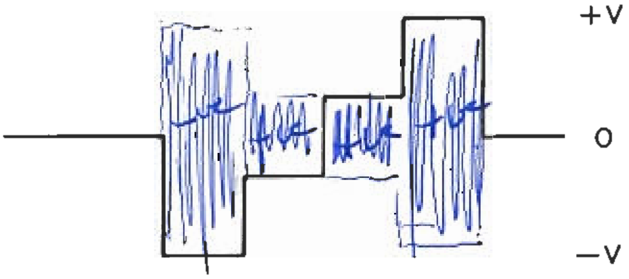
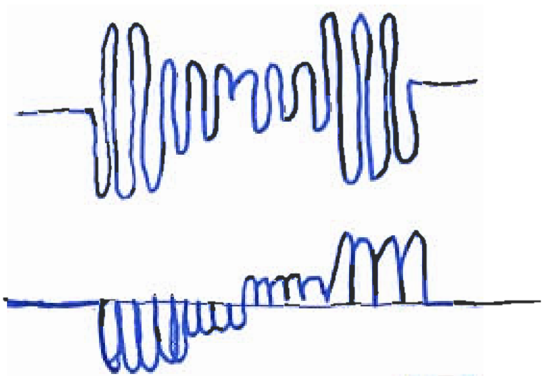
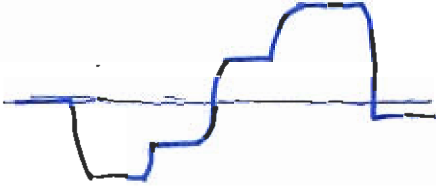


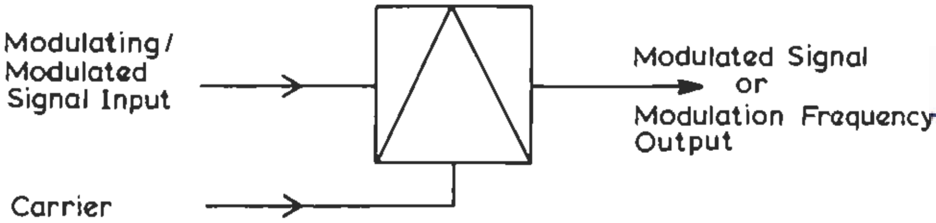
Fig 1.17 Simple Modulating Waveform





Check your answer with your supervisor before proceeding further.

You have now seen that the actual operation of a demodulator is almost the same as that of a modulator. In practice, the MC1596 multiplier integrated circuit can be used either as a modulator or demodulator. The symbolic representation of a modulator, as shown in figure 1.18, may also be used for a demodulator.



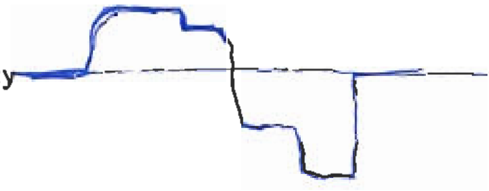


Fig. 1.18 Symbol for Modulator/Demodulator

1.9 TWO CHANNEL QUADRATURE MODULATION

The preceeding sub-sections have established that, provided the reference demodulating subcarrier is in the correct phase, the correct output will be obtained from the demodulator. If, however, the demodulating subcarrier is inverted (or phase shifted by 180°), the inverse of the original modulating signal is obtained at the demodulator output.

If the demodulating carrier is phase shifted by exactly 90° no output is produced by the demodulator after filtering. This fact enables two channels of information to be sent using only one carrier frequency. Two carriers are used at the same frequency but with a 90° phase relationship, this is known as QUADRATURE MODULATION.

Quadrature Modulation

If two suppressed-carrier modulators are fed with reference carriers in quadrature, they will both produce outputs at the same frequency, but again in quadrature to each other. If these two resulting modulated signals are then added together, since they are both of the same frequency, the resultant signal will also be a sine wave of this frequency, but of some intermediate phase which will be dependent on their relative amplitudes. This is illustrated in figure 1.19.

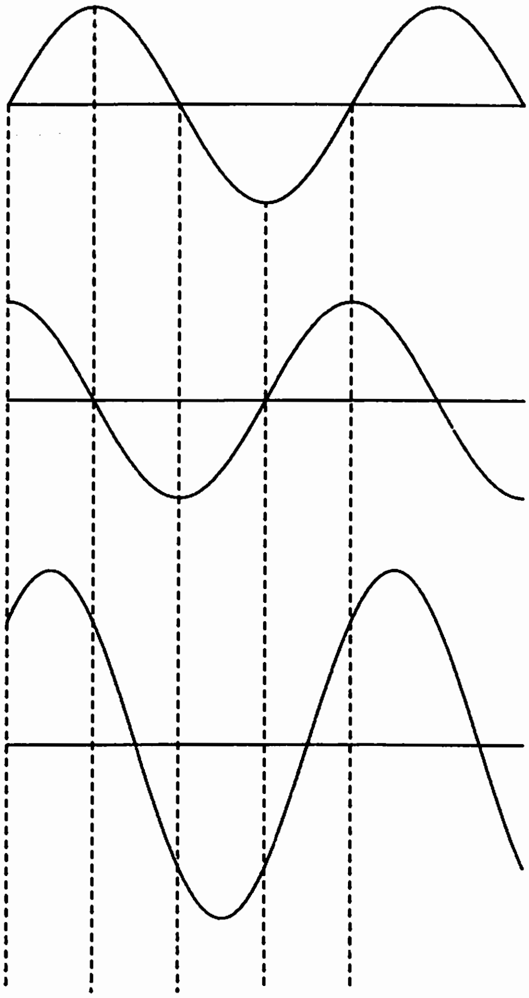


Figure 1.19 Addition of Two Sine Waves in Quadrature

Demodulation of this quadrature-modulated signal can easily be achieved by using two demodulators fed with reference carriers in quadrature. It is, however, very important that the phase difference between the two modulating carriers is exactly 90°. This also applies to the two demodulating carriers. The phase of the reference carrier fed to each demodulator must be exactly 90° to the carrier of the other, unwanted, signal, if *perfect separation* (i.e. no crosstalk) is to be achieved.

The three main characteristics of suppressed-carrier modulation can now be listed as follows:-

(a) The amplitude of the envelope is directly proportional to the amplitude of the modulating signal.

(b) The phase of the modulated signal is dependent on the polarity of the modulating input.

(c) Two signals may be transmitted together by adding the outputs of two modulators fed by reference carriers in quadrature.

1.10 CHROMINANCE TRANSMISSION WITH SUPPRESSED CARRIER MODULATION

The three basic characteristics of suppressed-carrier modulation make it an ideal method to transmit the two colour difference signals, both of which can have either positive or negative values.

A simplified schematic of the chrominance signal path is shown in figure 1.20.

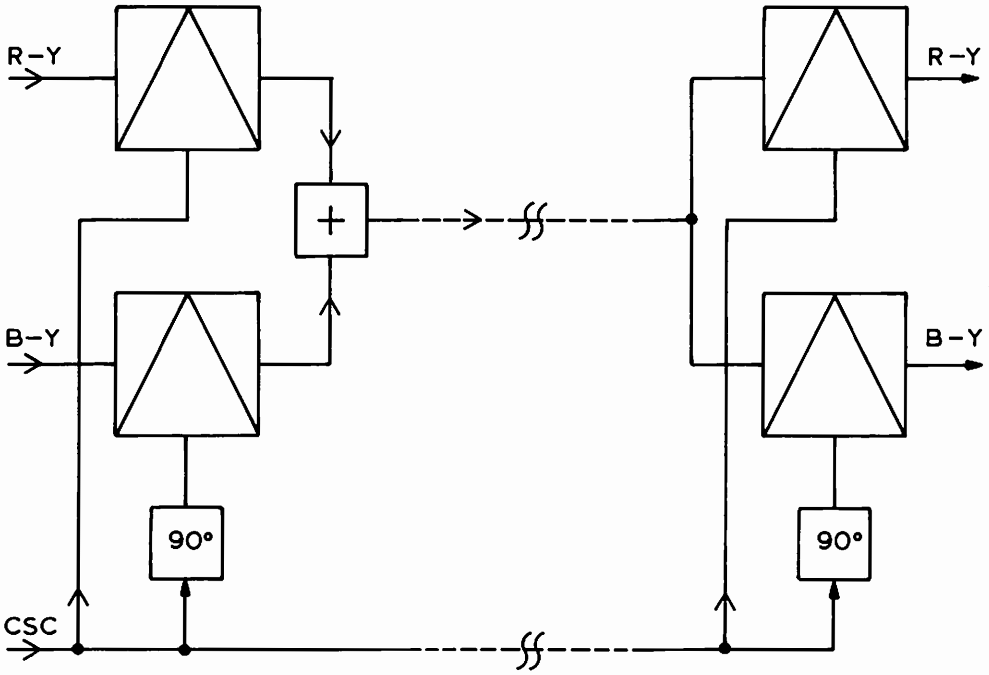


Figure 1.20 Basic Chrominance Signal Transmission

1.11 REQUIREMENT OF THE COLOUR BURST

It has been shown that it is very important to ensure that the phases of the demodulating carriers are exactly the same as those used by the modulators. In figure 1.20, this is achieved by supplying them both from the same feed of colour subcarrier. This implies a separate transmission path for the reference signal, with exactly the same amplitude and phase characteristics as the chrominance path. This is not possible in practice.

A practical solution to this problem is to use an oscillator in the decoder as the demodulating carrier. This oscillator must be locked accurately in frequency and phase to the modulators' reference carrier. To achieve this, a sample of the modulators' reference carrier is sent on the same transmission path as the chrominance signal. As they cannot both be sent at the same time the sample, known as the COLOUR BURST, is sent during the back porch of each line, except for nine lines during the field sync interval. This colour burst takes the form of about ten cycles of reference subcarrier.

Colour Burst

A negative (B - Y) component only is chosen for the reference burst.

Figure 1.21 shows the finalised chrominance signal transmission path using a separate demodulating phase-locked oscillator, which is usually referred to as a B.L.O. (Burst Locked Oscillator)

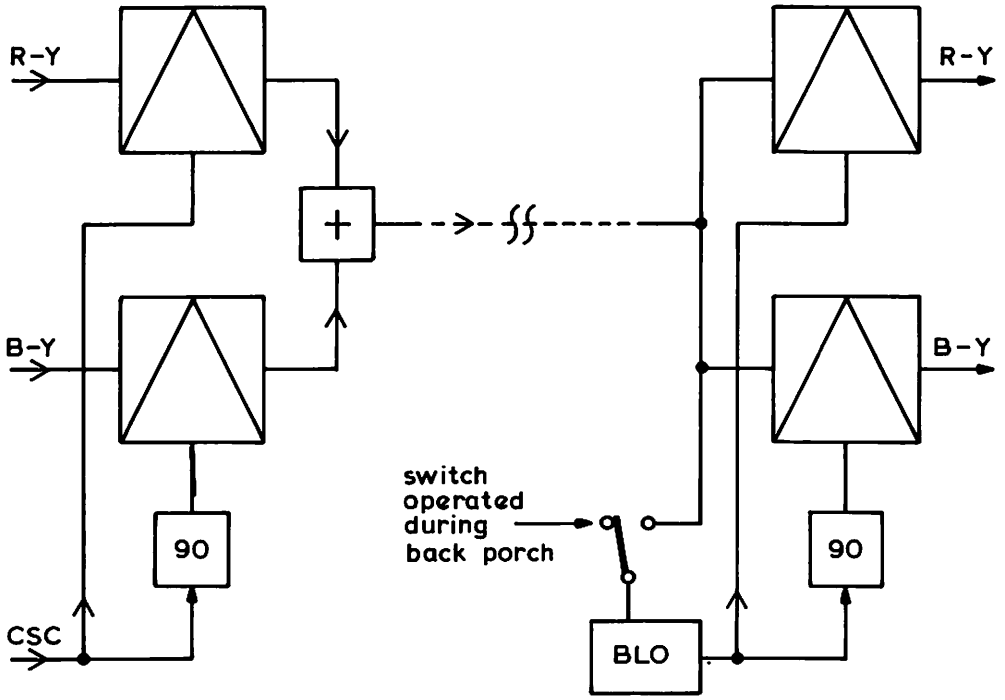


Fig 1.21 Chrominance Signal Transmission Path

Now view the summary tape on suppressed carrier modulation.

NOTES

NOTES

SECTION 2

PHASOR REPRESENTATION OF SUPPRESSED CARRIER MODULATION

2.1 PHASOR REPRESENTATION

Phasor Representation

Whatever colour difference signals are produced by a picture source, when coded they will result in a chrominance signal which is sinusoidal.

The variations of the two colour difference signal amplitudes are transferred to variations of the subcarrier amplitude and phase in the coder. The combined amplitude and phase of a sine wave may be represented and monitored, vectorially, and this method is frequently used.

2.2 PHASOR AXES

The chrominance signals corresponding to (R - Y) sin ωt and (B - Y) Cos ωt are in quadrature, i.e. they differ in phase by 90°. If the value of either colour difference signal is negative, this will result in an inversion of its corresponding subcarrier, i.e. 180° phase shift.

Considering the separate outputs of the two modulators, there are four possible phases, i.e. positive (R - Y), negative (R - Y), positive (B - Y) and negative (B - Y). These can be represented as shown in figure 2.1.

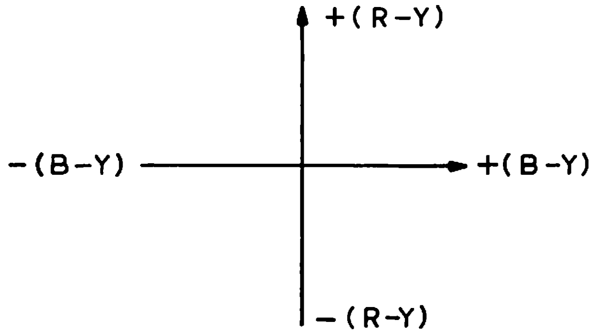


Figure 2.1 Phasor Representation of the Modulator Outputs

In Section 1 you established the amplitudes and polarities of both the colour difference signals for the fully saturated primary and complementary colours. The relative amplitudes and phases of their corresponding chrominance signals can now be represented on a phasor diagram, as shown in figure 2.2.

At this stage, it is useful to consider the chrominance vectors in 'j notation'. The (B – Y) components will lie on the real axis and the (R – Y) components on the imaginary or 'j' axis. The resultant vector obtained by combining the output of the two modulators is the point plotted at $C = (B - Y) + j(R - Y)$.

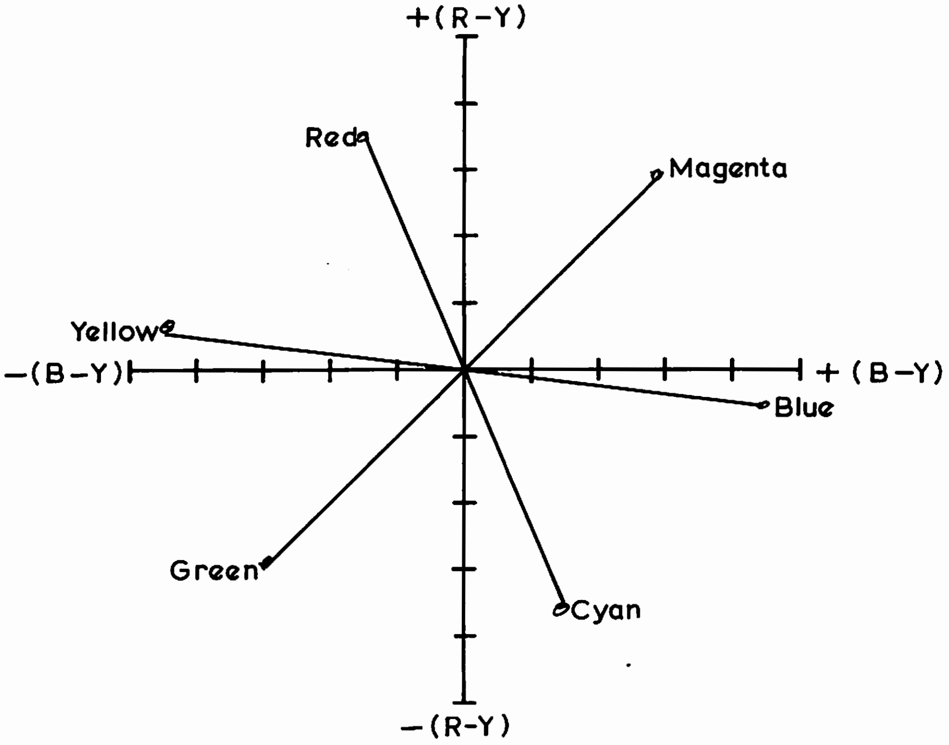


Figure 2.2 Phasor Representation of the Chrominance Signal

The chrominance phasors can be represented in polar form, i.e. $C \angle \theta$ where:

$$C = \sqrt{[(R - Y)^2 + (B - Y)^2]}$$

and

$$\theta = \tan^{-1} \frac{(R-Y)}{(B-Y)}$$

From those expressions the amplitudes and phases of each component can be calculated. These figures are tabulated in figure 2.3

j Real

Colour	R	G	B	Y	R-Y	B-Y	Chrom	Angle
White	100	100	100	100	0	0	0	-
Yellow	100	100	0	89	+ 11	- 89	90	173°
Cyan	0	100	100	70	-70	+30	76	293°
Green	0	100	0	59	- 59	- 59	83	225°
Magenta	100	0	100	41	+ 59	+ 59	83	45°
Red	100	0	0	30	+70	-30	76	113°
Blue	0	0	100	11	- 11	+ 89	90	353°
Black	0	0	0	0	0	0	0	-

Figure 2.3 Chrominance Phasor Amplitudes and Phase Angles

The table in figure 2.3 enables the relative amplitude and phases of the chrominance signal to be assessed. The main features found from your phasor diagram and the table of figure 2.3 are tabulated in figure 2.4.

HUE	POLARITY OF COL. DIFF. SIGS		MODULATOR OUTPUT PHASES		RESULTANT CHROMINANCE PHASE
	R-Y	B-Y	R-Y	B-Y	
Magenta	+	+	90°	0°	1st Quadrant
Red & Yellow	+	-	90°	180°	2nd Quadrant
Green	-	-	270°	180°	3rd Quadrant
Cyan & Blue	-	+	270°	0°	4th Quadrant

Figure 2.4 Summary of Chrominance Signal

2.3 INFORMATION CONTAINED IN PHASOR REPRESENTATION

From the table in figure 2.3 which was summarised in figure 2.4, it can be seen that the angle of the combined chrominance phasor depends on the HUE of the colour transmitted.

Hue

The AMPLITUDE of the chrominance phasor depends on the SATURATION and INTENSITY of the colour transmitted.

Amplitude
Saturation
Intensity

Before continuing with Section 3, plot a phasor diagram on graph paper for the following RED colours of different amplitudes and saturations. This will be easier for you to do if you first establish a table of the relevant values of R, G, B and Y, together with their consequent values of (R – Y) and (B – Y).

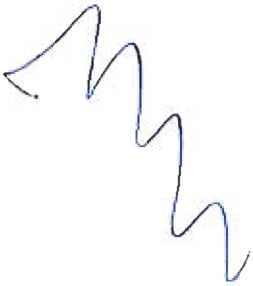
(a) 100% amplitude, 100% saturation

(b) 50% amplitude, 100% saturation

(c) 100% amplitude, 50% saturation

(d) 50% amplitude, 50% saturation

					j	Real
	R	G	B	Y	(R-Y)	(B-Y)
	100	0	0	30	70	-30
b	50	0	0	15	35	-15
c	100	50	50	65	35	-15
	50	25	25	32.5	17.5	-7.5



NOTES

Your phasor diagram should confirm that the chrominance vectors for all these pure red colours have the same phase angle. Note the effect of reducing the amplitude of a 100% saturated colour.

Brightness

The amplitude of the chrominance phasor is thus dependent not only on the saturation of a colour; but also on its BRIGHTNESS.

Note that achromatic pictures (e.g. black, grey and white) have zero colour difference and chrominance signals.

The effect of adding the chrominance signal to the luminance signal can now be examined.

SECTION 3

THE COMPOSITE CODED VIDEO SIGNAL

3.1 DERIVATION OF THE CODED VIDEO SIGNAL

Coded Video

In sub-section 2.2 the amplitudes of the luminance and chrominance signals for each step on the colour bar waveform were established. The composite CODED VIDEO is simply an addition of these two signals. The effect of combining these signals is shown in figure 3.1

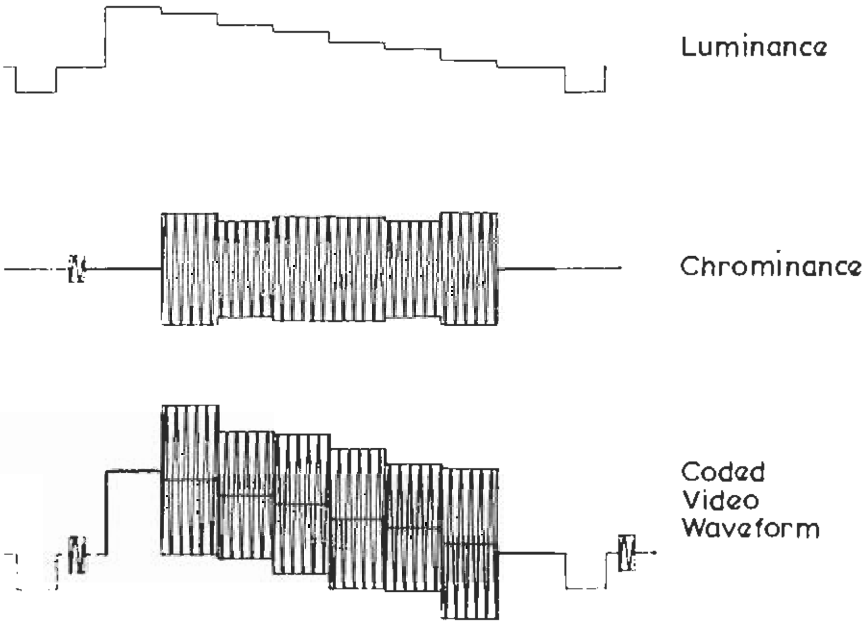


Figure 3.1 Composite Coded Video Signal Waveforms.

With reference to the coded video waveform shown in figure 3.1, write down the main features you notice and state any reasons why you think this waveform is not suitable for transmission.

Because it goes over 1 Volt. + below 0V

NOTES

If this composite coded video signal were transmitted it would be distorted by the overall system performance. When the chrominance signal is added on to the luminance signal, the overall amplitude is increased. If no action was taken, the transmitter would be over-modulated and the extreme excursions of the chrominance signal would be lost. The modulating signal gain at the input to the transmitter could be reduced to avoid this. However, this would result in a lower picture signal amplitude when detected in the viewer's receiver.

If the composite coded video signal were transmitted at such a level as to avoid over modulation, what would be the effect of this on the resulting display?

Very Noisy -

An examination of the coded video signal reveals that the problem is greatest for colours such as yellow and blue. These colours also represent the maximum value for the (B – Y) signal, with only a small ammount of (R-Y). Colours such as Cyan and Red contain more R-Y than B-Y, but represent less of a problem as they are not so near the extremes of luminance as Blue and Yellow. The problem of over modulation is tackled by treating B-Y and R-Y separately.

3.2 PRINCIPLES OF WEIGHTING

Earlier in this module the need for compatability and reverse compatability was established. In consequence the luminance signal component of our coded video signal cannot be changed. This implies that the chrominance signal must be modified.

Any reduction in chrominance signal amplitude will result in a reduced chrominance signal-to-noise ratio. The amplitude of the (B – Y) video signal is reduced by just over a half and the (R – Y) video signal by about one eighth, a process known as weighting. The (B-Y) and (R-Y) colour difference signals after WEIGHTING are known as the U and V signals. Hence,

Weighting

$U = 0.493\ (B - Y)$

and

$V = 0.877\ (R - Y)$

Using these factors, a final table of luminance and chrominance amplitudes can be produced. This is shown in figure 3.2

Colour	R	G	B	Y	U	V	Chrom	Angle
White	100	100	100	100	0	0	0	–
Yellow	100	100	0	89	– 44	+ 10	45	167°
Cyan	0	100	100	70	+ 15	– 61	63	284°
Green	0	100	0	59	– 29	– 52	59	241°
Magenta	100	0	100	41	+ 29	+ 52	59	61°
Red	100	0	0	30	– 15	+ 61	63	104°
Blue	0	0	100	11	+ 44	– 10	45	347°
Black	0	0	0	0	0	0	0	–

Figure 3.2 Table of Luminance and Chrominance Values for 100% Bars

(Note - The phase angle (θ) of the chrominance phasor is measured relative to the + (B - Y) axis).

Using the values shown in this table, the NTSC colour bar waveform can now be established.

Using the values shown in Fig. 3.2, draw an NTSC composite coded colour-bar waveform on graph paper. Remember that these values are in T-units and should be multiplied by 0.7 before plotting. The reference burst amplitude is 0.3 volts peak-to-peak and occurs from approximately 5.6 micro-seconds to 7.8 micro-seconds relative to the leading edge of line syncs. Use scales of 0.1 V/cm for signal amplitude and one colour bar period (6.5 micro-seconds approx)/cm for the time scale.

Before continuing, ask your supervisor to check your waveform.

The colour bar waveform that you have drawn is that for 100% amplitude, 100% saturated, colour bars. This waveform is known colloquially as 100% bars.

3.3 STANDARD NOMENCLATURE OF COLOUR BARS

Colour Bars

A COLOUR BAR waveform has four basic amplitude parameters, these may be derived from their R, G and B component values. The parameters may be expressed as four percentage numbers, e.g. 100/0/100/0, defined as follows:-

First Number - The percentage value of the R, G and B signals present in the white bar.

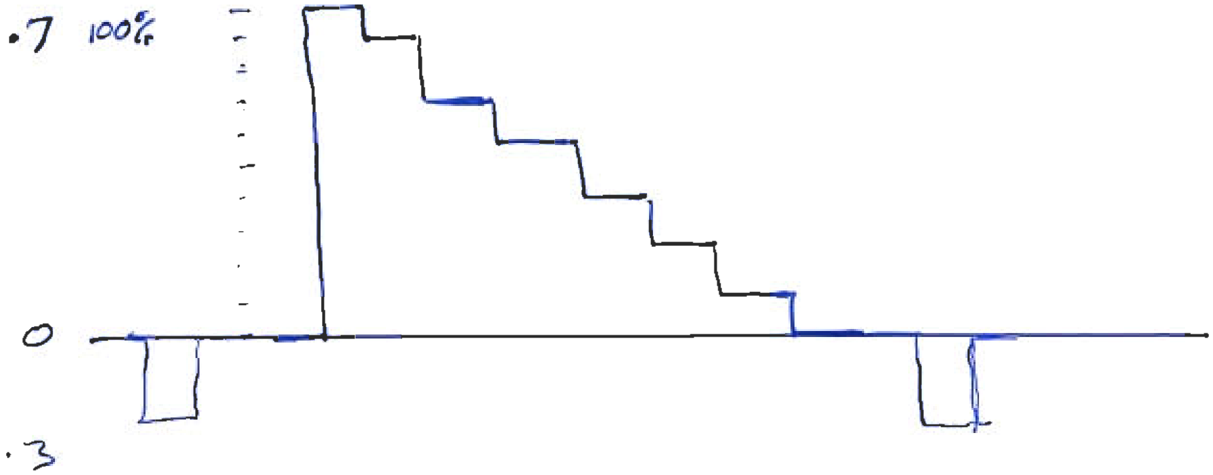
Second Number - The percentage value of the R, G and B signals present in the black bar.

Third Number - The maximum percentage value of the R, G and B signals for the coloured bars.

Fourth Number - The minimum percentage value of the R, G and B signals for the coloured bars.

The three component signals for 100/0/100/0 colour bars (known as 100% bars) are shown, together with the composite coded signal in figure 3.3.

NOTES



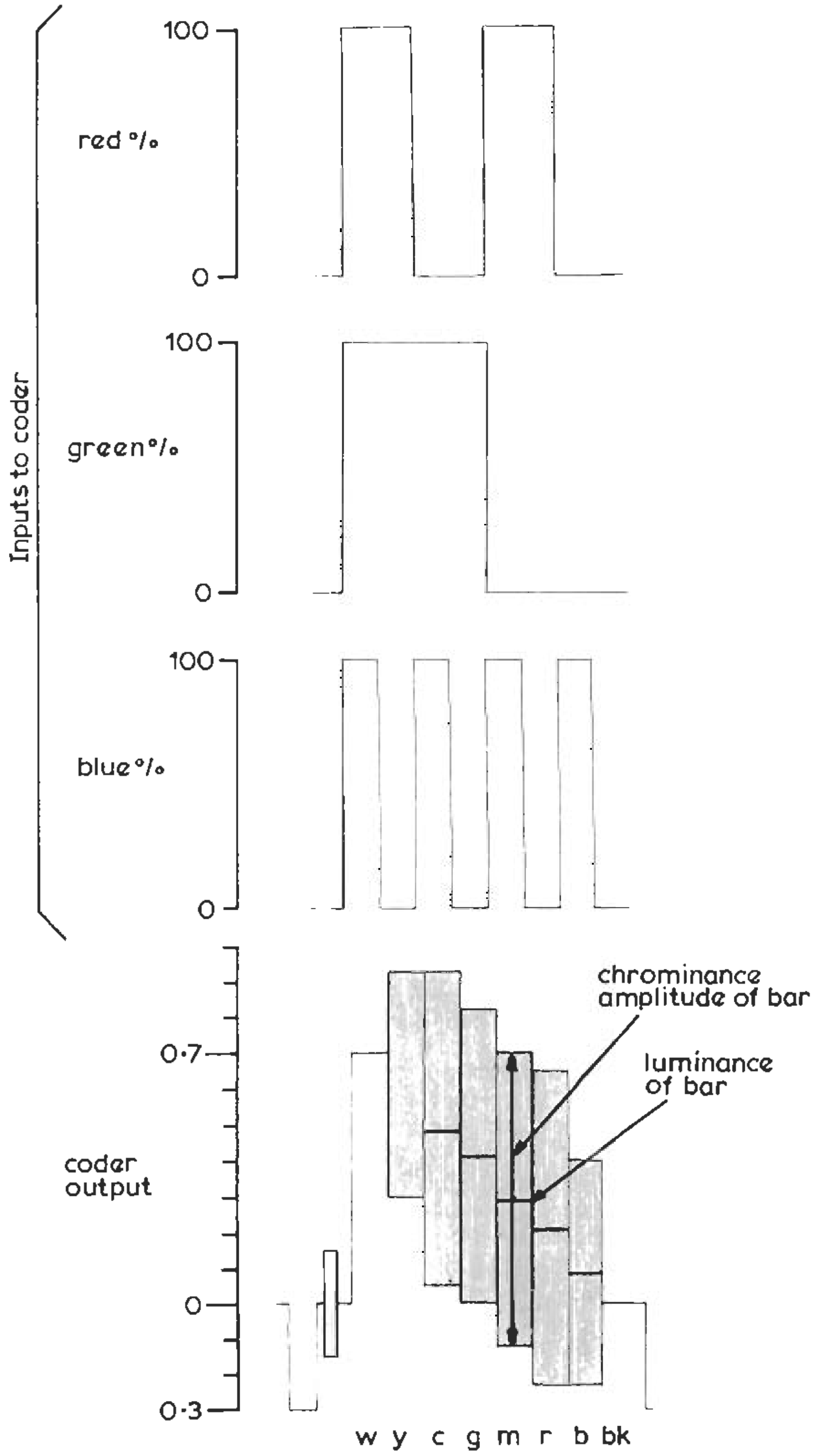


Figure 3.3 100/0/100/0 (100% Bars) Colour Bar Waveforms

3.4 MAIN FEATURES OF 100/0/100/0 BARS

The main features of 100/0/100/0 colour bars at the standard level are:-

(a) Luminance level for the white bar is 0.7V (100%)

(b) Luminance level for the black bar is 0V (Blanking level)

(c) Positive chrominance peaks for yellow and cyan are at the same level (because of the weighting factors chosen for the U and V signals)

(d) By symmetry of the waveform, the negative peaks of the red and blue bars are at the same level.

(e) The positive peaks of the magenta chrominance signal are at white level.

(f) The negative peaks of the green chrominance signal are within 3mV of black level.

Note: This last feature of the 100% bars waveform can usefully be used as a check for correct chrominance amplitude relative to the luminance amplitude.

This colour bar waveform is very useful as a colour line-up signal. It is difficult, however, to identify the change between the end of the black bar and the start of the front porch of line blanking. To alleviate this problem, most colour bar generators have the durations of each coloured bar slightly reduced to allow sufficient time for a further white bar at the end of the line.

3.5 OTHER COLOUR BAR SIGNALS

100% bars are only used internally and are never transmitted. They represent a very stringent test and are not representative of colours normally encountered in practice. So 95% bars are used as a transmitted test signal. Also, with reference to the 100% Bars waveform in Figure 3.3, it can be seen that the negative peaks of the chrominance signal for magenta, red and blue extend below blanking level. Whilst for an average picture, which generally does not contain highly saturated colours, this is no problem, the fully saturated colours for the 100% Bars signal could have caused mistriggering on line timebases of the existing monochrome receivers of the time.

3.6 95% BARS

95% Colour Bars still have an amplitude of 100% (for white and the colours), but all the colours are de-saturated with 25% of white. The standard nomenclature for 95% Bars is thus 100/0/100/25.

Whilst 95% bars are generated electrically as 75% saturated, they are displayed as 95% saturated due to the non-linearity of the C.R.T.

The characteristics of 95% bars can be seen from the waveform in Figure 3.4, and may be summarised as,

(a) Luminance level for white bar is 0.7 volt,

(b) Luminance level for black bar is 0.0 volt,

(c) Positive chrominance peaks for yellow and cyan are at the same level (above white level).

(d) Negative chrominance peaks for the red and blue bars are equal, and are equal to black level.

(e) Positive chrominance peaks of magenta are at white level, but

(f) Negative peaks of green lie above black level.

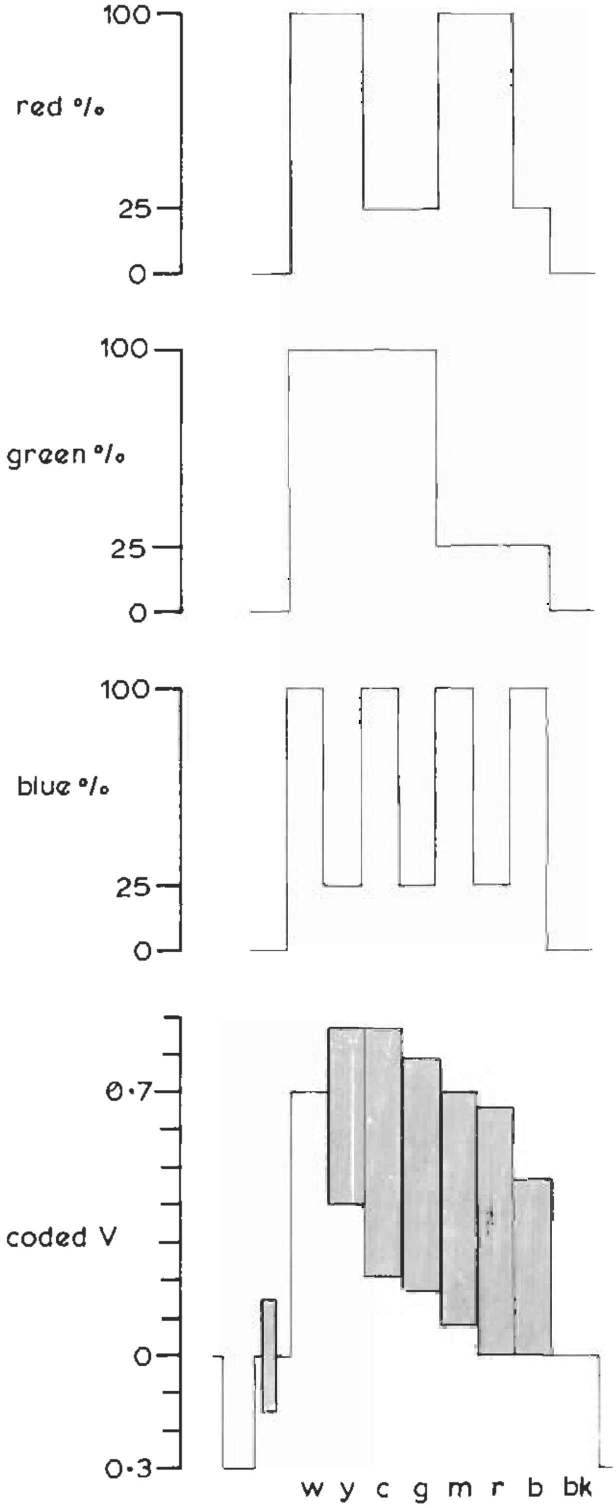


Figure 3.4 100/0/100/25 Colour Bars
RGB inputs and composite output of coder

3.7 E.B.U. BARS

The European Broadcasting Union has adopted another standard of colour bars as an international line-up signal. The value of the R, G and B signals are adjusted to ensure that chrominance positive peaks do not extend above white level.

The standard nomenclature for E.B.U. bars is 100/0/75/0. Because the maximum amplitude of the R, G & B signals for the six coloured bars is only 75% of white level, E.B.U. bars are sometimes referred to as 75% bars.

The characteristics of E.B.U. bars can be seen from Figure 3.5 and may be summarised as:-

(a) Luminance level for white bar is 0.7 volt.

(b) Luminance level for black bar is 0.0 volt.

(c) Positive chrominance peaks for the yellow and cyan bars are equal and the same as white level.

(d) Negative chrominance peaks for the red and blue bars are equal but lie below black level.

(e) Positive peaks of the magenta chrominance lie below white level.

(f) Negative peaks of the green chrominance signal occur at black level.

(Note that EBU bars are radiated by the IBA as a test signal, whilst the BBC uses 95% bars). Now go to the demonstration unit and, after reading the introduction, undertake demonstration 3.1.

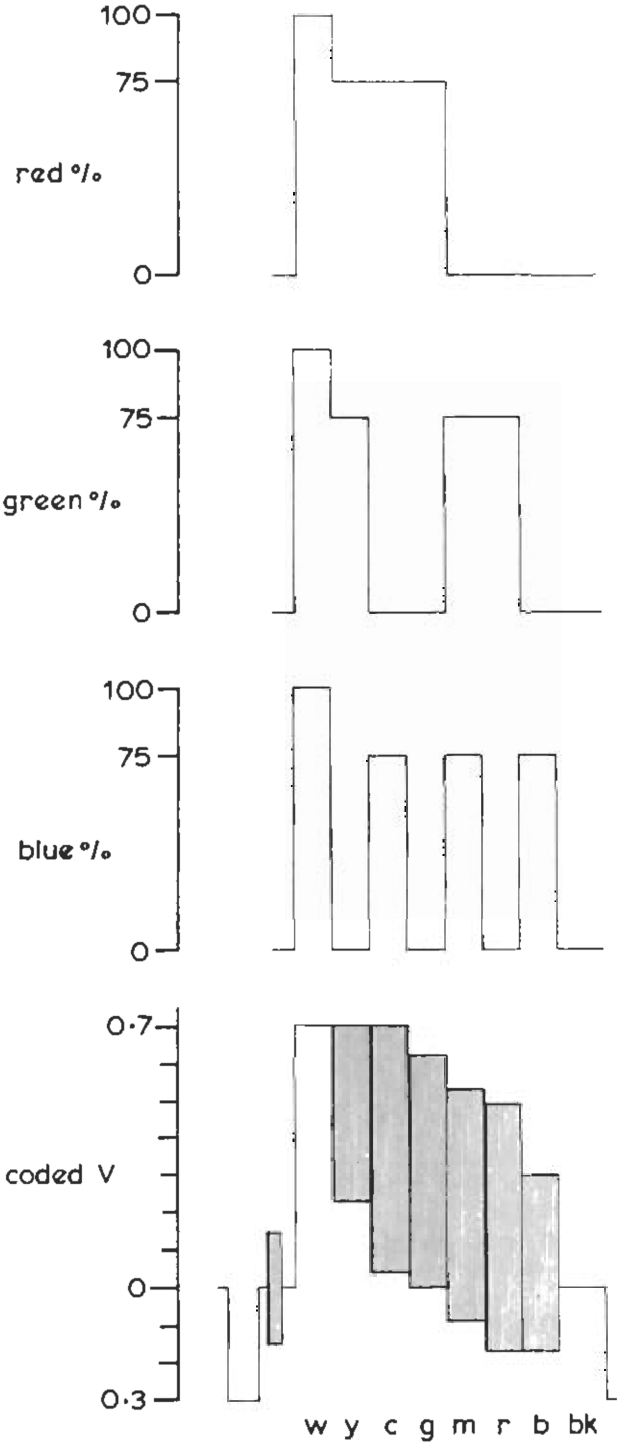


Figure 3.5 100/0/75/0 Colour Bars
RGB inputs and composite output of coder

3.8 NTSC CODING AND DECODING

NTSC System

All the main features of an NTSC type colour transmission SYSTEM for 625 lines have now been considered. The principles which have been examined in detail so far can now be included in a block diagram for an NTSC coder and decoder. Initially these two units can be shown connected as in figure 3.6. Both the coder and decoder have certain input and output signal requirements.

On the NTSC system block diagram, figure 3.6, label the inputs and outputs of the coder and decoder. On a separate sheet, list the main functions which the inputs to the coder have to perform and summarise the methods used to produce the output signals from the decoder.

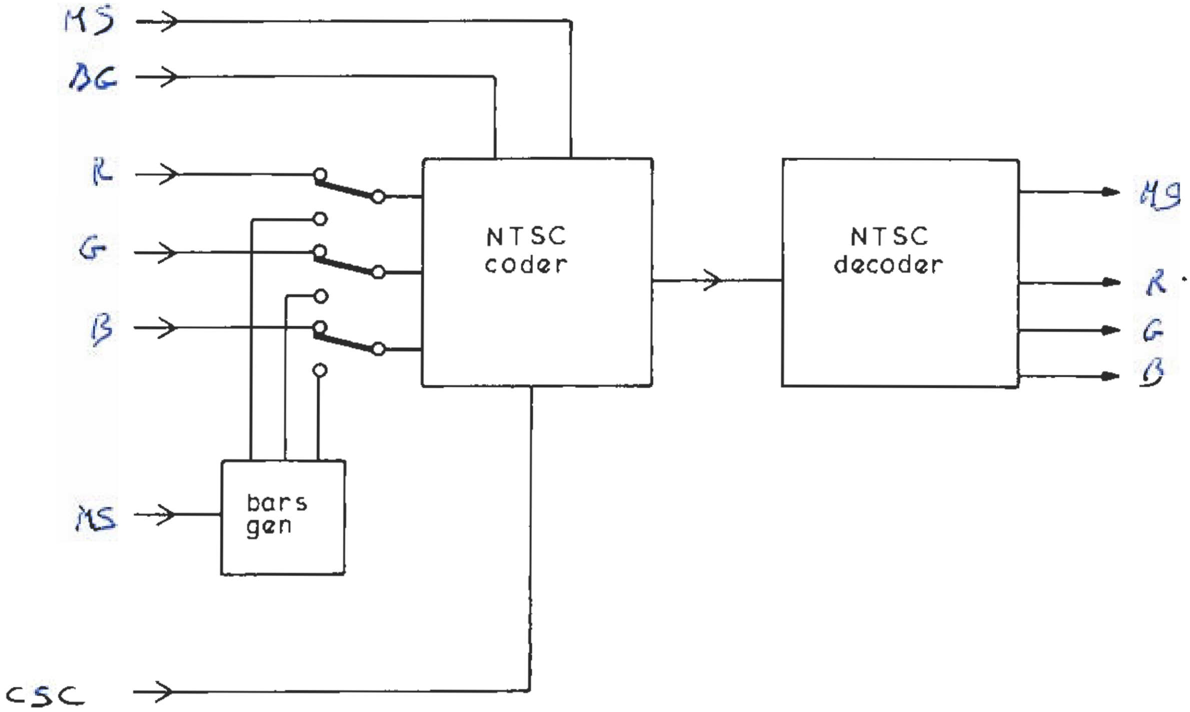


Figure 3.6 Interconnection of an NTSC Coder and Decoder

The colour bar generator can either be a separate unit or an integral part of the coder.

The main features of the NTSC colour television system have been examined and these can now be included in block diagram form for a coded transmission path.

NOTES

3.9 NTSC CODER

NTSC Coder

The signal source produces R, G & B outputs which are fed to a coder. A typical NTSC CODER is shown in figure 3.7 and has the following features:-

(a) production of a luminance (or Y) signal such that:

$Y = 0.3R + 0.59G + 0.11B.$

(b) production of weighted colour difference signals by using a (usually passive) matrix such that:

$U = 0.493(B - Y)$ and
$V = 0.877(R - Y)$
and bandlimiting of U and V signals.

Note:-
$U = 0.493\ [B - (0.3R + 0.59G + 0.11B)]$
$\quad = 0.493\ (0.89B - 0.3R - 0.59G)$
and $V = 0.877\ (0.7R - 0.59G - 0.11B)$

$V = \cdot 877 \left(R - (\cdot 3R + \cdot 59G + \cdot 11B\right)$

(c) the V signal modulates the colour subcarrier.

(d) a short period of negative-going voltage is added to the U signal to generate the colour burst in the –U phase during the back porch.

(e) a 90° phase shift is applied to the reference sub-carrier fed to the U modulator.

(f) the U signal modulates the 90° phase-shifted sub-carrier.

(g) the outputs of the two modulators are added to produce the chrominance signal.

(h) the harmonics are filtered from the chrominance signal.

(i) addition of mixed syncs to the luminance signal.

(j) the composite luminance signal is delayed to match the delays introduced by the chrominance filters and modulators.

(k) the chrominance signal is then added to the composite luminance signal to produce the composite coded output. On some modern equipment this is often labelled C.V.B.S. (Chrominance, Video, Burst and Syncs).

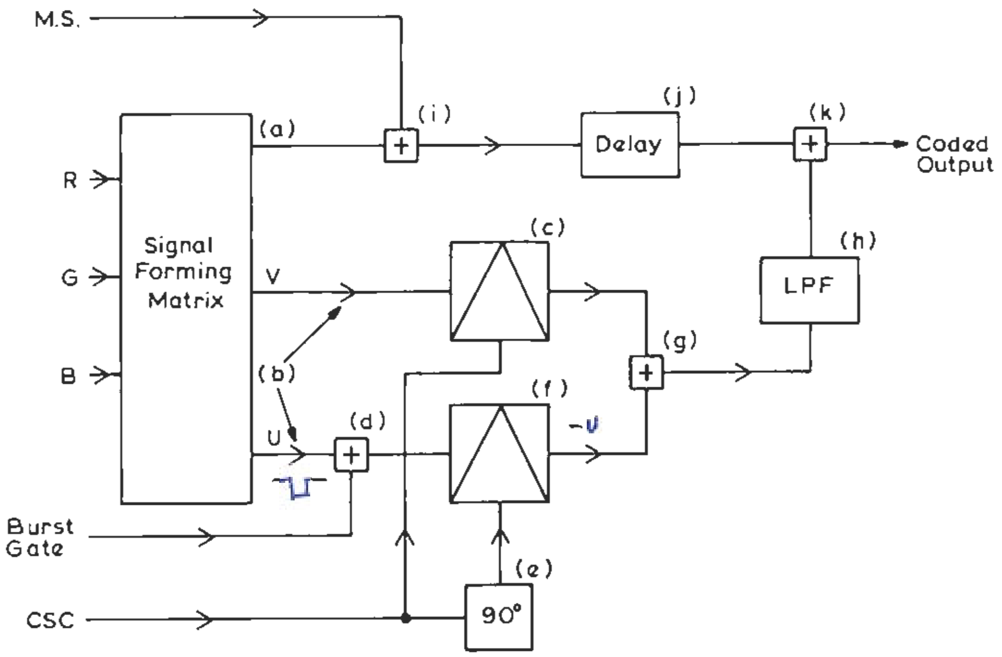


Fig 3.7 Simplified NTSC Coder

3.10 NTSC DECODER

NTSC Decoder

The input to the decoder is a composite coded video signal. A typical NTSC DECODER is shown in figure 3.8. It:

(a) Separates mixed-sync pulses from the video signal.

(b) Separates the luminance signal from the coded video input, using a band-stop filter to remove the chrominance.

(c) Separates the chrominance information from the coded input using a band-pass filter.

(d) Uses a switching signal derived from the mixed syncs to isolate the colour burst.

(e) Uses the ten cycles of reference sub carrier on the -U axis to phase lock a Burst Locked Oscillator (B.L.O.). This regenerated reference is arranged to lie on the V axis.

(f) Uses the output of the B.L.O. to demodulate the V chrominance component to obtain the (R – Y) signal.

(g) Phase shifts the B.L.O. reference by 90° to feed the U demodulator.

(h) Demodulates the chrominance in the U axis, using the 90° phase shifted reference subcarrier to obtain the (B – Y) signal.

(i) Filters residual subcarrier components from the demodulated colour difference signals.

(j) Provides a (G – Y) signal by matrixing the (R – Y) and (B – Y) signals such that:

$$(G - Y) = -\,0.3\,\frac{(R - Y)}{0.59} - 0.11\,\frac{(B - Y)}{0.59}$$

$$= -\,[0.51\,(R - Y) + 0.19\,(B - Y)]$$

(k) Delays the separated luminance signal to compensate for the delay in the chrominance filters (i)

(l) Adds the luminance signal to the three colour difference signals (R – Y), (B – Y) & (G – Y) to produce R, G & B outputs.

Now go to the demonstration equipment and carry out demonstrations 3.2 to 3.5

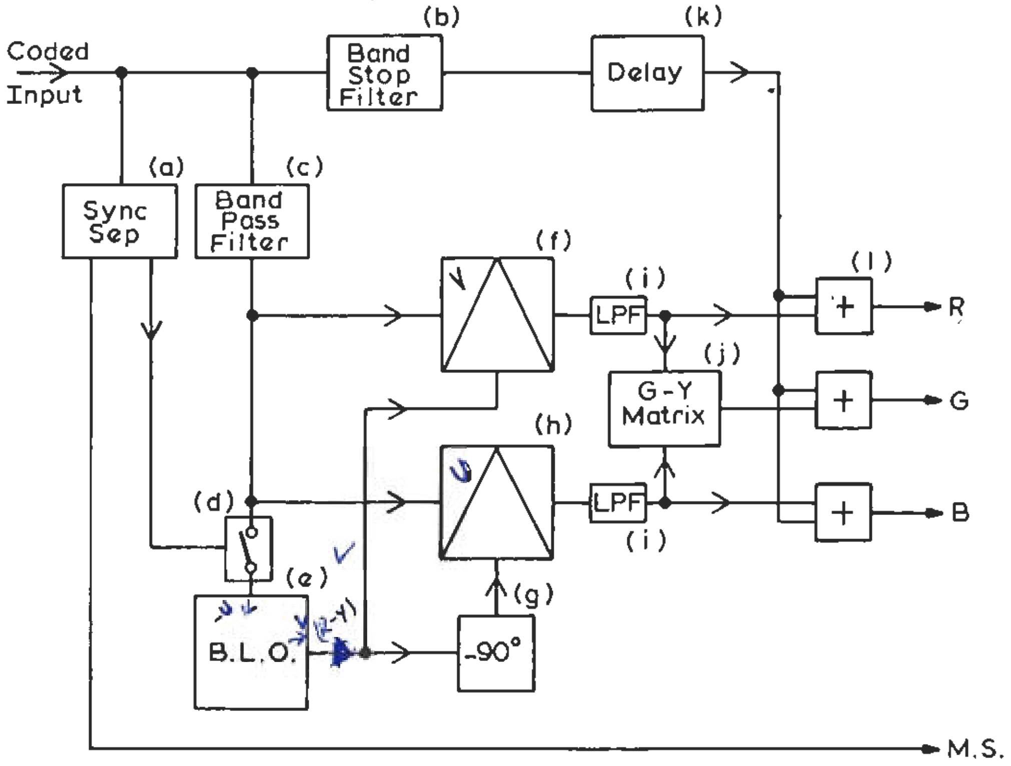
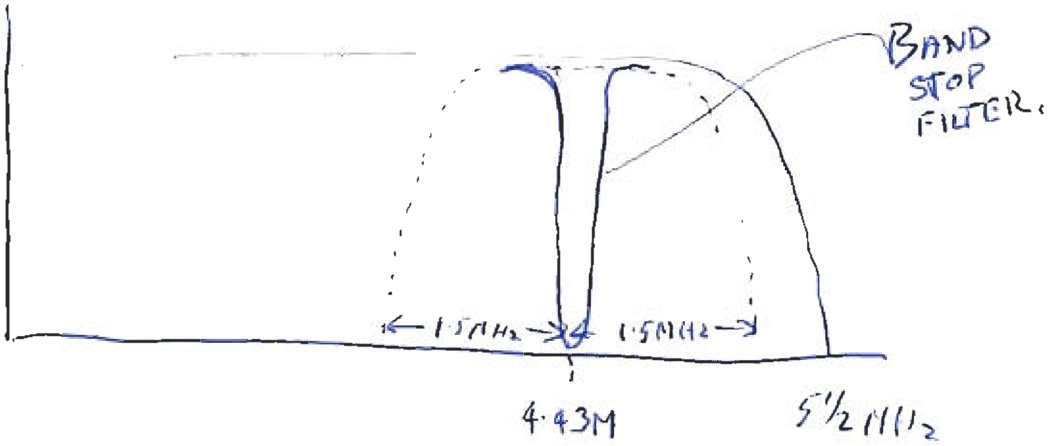


Fig. 3.8 Basic NTSC Decoder



NOTES

SECTION 4

DISTORTIONS

4.1 TYPES OF DISTORTION

It was shown in Section 3 that the amplitude of the chrominance signal determines the saturation of the display and that the phase of the chrominance signal determines its hue. It was also shown in the previous package that, owing to the non-linearity of the picture tube, the colour difference signals effectively convey brightness information. It is possible that a change in the amplitude and/or phase of the chrominance signal (relative to the burst) may take place during the transmission of the coded signal. This would cause errors in the reproduced picture. The possible distortions and the resulting errors are discussed separately in the following sub-sections.

4.2 DIFFERENTIAL GAIN DISTORTION

Consider a luminance signal rising in 5 steps from black level to white level. To this signal is added a subcarrier component of constant amplitude and phase.

Transmission path errors could cause the amplitude of the received subcarrier to vary (either increase or decrease). If this amplitude variation is dependent on the luminance level, then this effect is known as DIFFERENTIAL GAIN distortion. An example of this is shown in figure 4.1(b).

Differential Gain

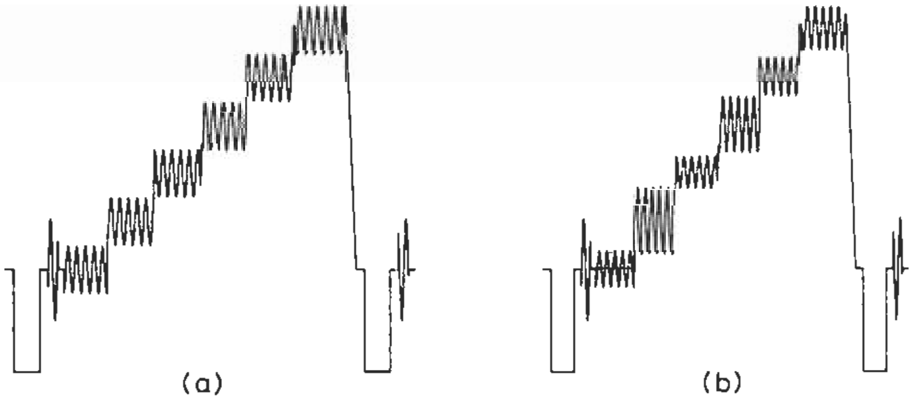


Fig. 4.1 A coded Video Signal
(a) Without and (b) with Differential Gain Distortion

Differential gain distortion results in the demodulated colour difference signals having incorrect amplitudes. As a consequence the resulting display will exhibit saturation *and brightness* errors.

4.3 DIFFERENTIAL PHASE DISTORTION

If the signal of Figure 4.1a is demodulated the output should be a steady d.c., as shown in Figure 4.2a. However, if transmission path errors cause the phase of the chrominance signal to vary, and this variation is a function of luminance level, then the demodulator output is no longer constant. The effect is known as DIFFERENTIAL PHASE distortion and is shown in Figure 4.2b.

Differential Phase

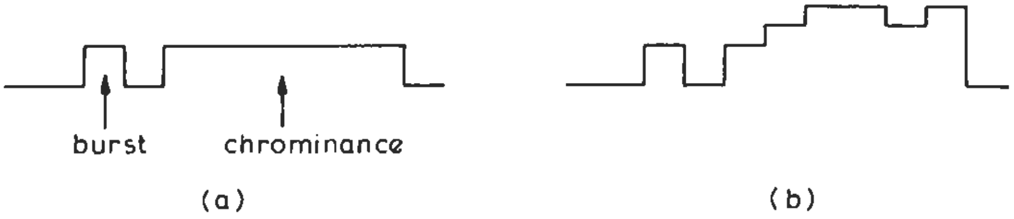


Figure 4.2 Waveform Produced After Demodulating a Signal (a) Without and (b) with Differential Phase Distortion

Hue Errors

Differential phase distortion results in HUE ERRORS which cannot be corrected by a shift in demodulator carrier phase.

Differential phase distortion also results in saturation and brightness errors, because the demodulated colour difference signals must change in amplitude if the phase of the demodulator input is altered.

Differential distortions are generally caused by transistor inter-electrode capacitances changing with the signal across them. Careful circuit design can minimise the effects of this.

Note: Although differential gain and phase distortions are examined separately, they are usually found together.

There is another source of phase distortion which may be present in a colour system. This occurs when the colour burst or demodulator reference carrier does not lie on the correct axis. This can happen if the burst is removed and is then re-inserted into the signal path at a later stage (e.g. in a videotape recorder or vision mixer), or if the B.L.O. in the demodulator does not lock in the correct phase. The latter effect frequently happens in domestic television receivers. Such distortions are particularly well handled by the PAL system as will be seen later.

If the B.L.O. in an NTSC decoder locked up a few degrees out of phase, what effect would you expect this to produce:-

(a) on the colour difference signals? ~~[illegible] would~~ amplitude would go down

(b) on the displayed picture? Hues would change

The effect of phase distortion is best seen on a monitor. Turn now to the practical unit and, undertake demonstrations 4.1 and 4.2. These simulate a colour television system in operation.

SECTION 5

BROADCAST COLOUR SYSTEMS

5.1 THE NTSC SYSTEM

Sections 3 and 4 explained the principles of an NTSC system. Any phase distortion (differential or overall) varies the phase of the chrominance subcarrier during all or part of the active picture relative to the colour burst. Because the subcarrier phase dictates the received hue, this produces hue errors. Many NTSC receivers capitalise on this to provide a user Hue control.

The NTSC system does have the advantage that the coded signal can easily be processed during the broadcast video chain, e.g. the coded signal can be faded to black without altering the luminance to chrominance amplitude relationship.

5.2 THE SECAM SYSTEM

SECAM System

The SECAM SYSTEM transmits only one colour difference signal at a time. During one line the subcarrier is frequency modulated by one colour difference signal, and during the next line the other colour difference signal is fed to the modulator. The use of frequency modulation makes the system able to withstand considerable amounts of amplitude and phase distortion, but the effects of multipath reception may be noticable.

Unlike the NTSC and PAL systems, the two carriers which are modulated by the two colour difference signals have different frequencies (282 × line frequency and 272 × line frequency) for zero modulation (neutral scenes). The deviations of the two modulators are also different. To enable the decoder to detect the colour difference signal sequence, nine lines of synchronisation signals are sent during field blanking.

A typical SECAM coder is shown simplified in Figure 5.1.

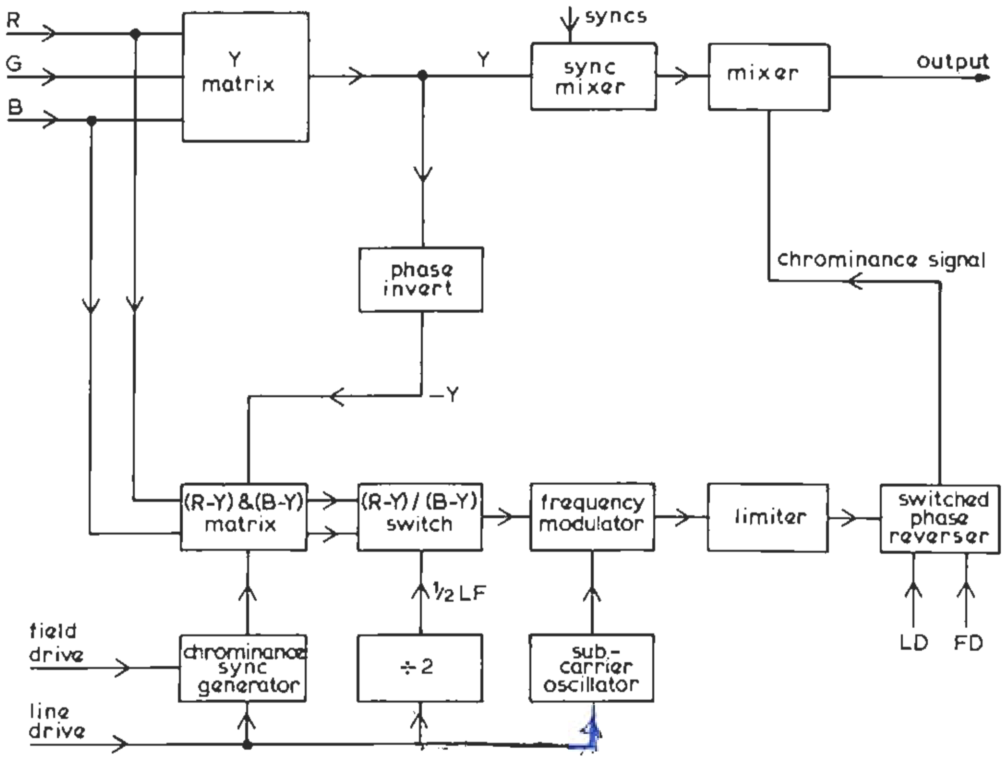


Figure 5.1 A Simplified SECAM Coder Block Diagram

In the decoder a delay of one line duration is provided to make both modulated colour difference signals available at any time for demodulation. Figure 5.2 shows how this is achieved.

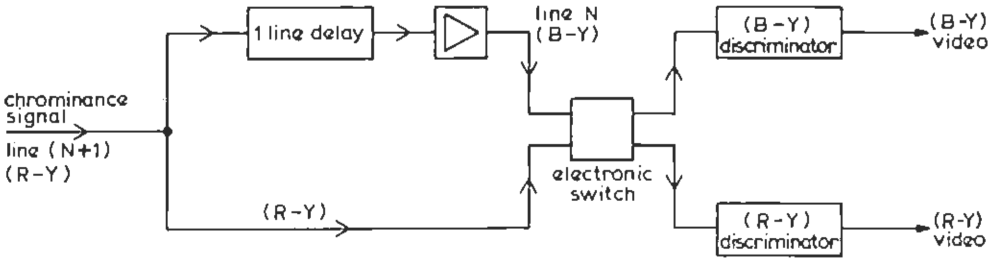


Figure 5.2 Use of delay line in a SECAM decoder

If a coded SECAM signal were to be faded to black, as may be required in a mixer, the luminance signal would be reduced in amplitude. However, the same amplitude of colour difference signals would still be present after demodulation (giving over-saturated pictures) until insufficient chrominance signal was available, resulting in a monochrome picture. A SECAM vision mixer must demodulate the signals prior to fading (or mixing) in order to overcome this problem. Most studios involved in the production of signals for SECAM broadcasting in fact use the PAL system for ease of handling. The signal is subsequently 'trans-coded' prior to transmission.

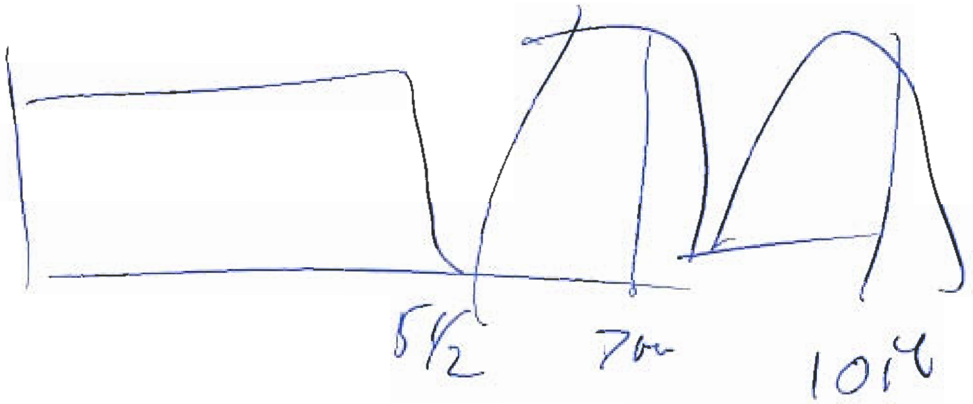
5.3 THE PAL SYSTEM

PAL System

The PAL SYSTEM uses a modification to the NTSC system designed to reduce the effect of phase distortions.

The V modulator output has a 180° phase inversion applied on alternate lines. (Phase Alternating Line).

This has the effect on alternate lines of altering the direction of any hue change produced. The errors can then be averaged, either by the eye or electronically. How this is achieved and the effect that phase distortions produce is examined in Section 6.



NOTES

R	G	B	Y	R-Y	B-Y	·493 U	·877 V	||	ϕ
0	100	100	·70	-·70	30	15	-61	·63	284

SECTION 6

THE PAL SYSTEM

6.1 PRINCIPLE OF THE PAL SYSTEM

The last practical observations you made demonstrated just how objectionable the effects of phase errors can be. Any modification to the system that can be adopted to reduce the effect of these will be beneficial. The phase errors you saw were overall phase errors, i.e. the decoder Burst Locked Oscillator was not locked in the correct phase.

Consider a magenta signal that undergoes a phase shift distortion. The phasor representation of this is shown in Figure 6.1

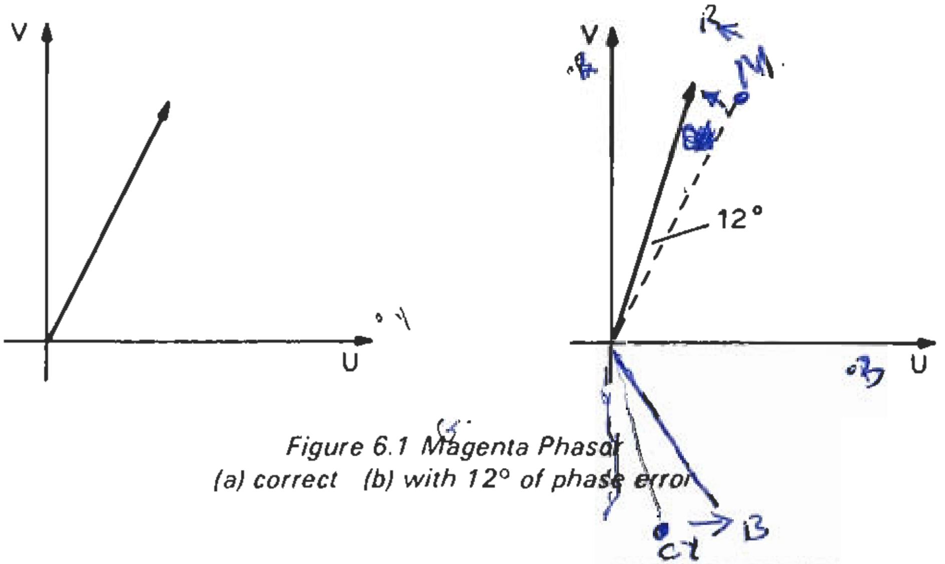


Figure 6.1 Magenta Phasor
(a) correct (b) with 12° of phase error

The effect of a positive phase error is to make the magenta appear too red.

What effect would the same error have on cyan? More blue

Draw a phasor diagram for 100% saturated cyan showing a positive phase error of 12° on this signal. What effect would this have on the reproduced colour?

Your answer should show that the cyan colour is reproduced as too blue. This effect could be likened to that of a negative phase error on magenta which would also make it appear too blue.

This means that a fixed phase error in one direction produces a different effect depending on the original colour, and hence phase of the chrominance signal. The PAL system utilises this fact to apply a degree of automatic correction for phase errors.

Any overall phase error, e.g. the B.L.O. incorrectly locking to the burst or the mean phase of the burst being incorrect, causes the decoding axes to rotate. This has the same effect as all the phasors being rotated by the same fixed angle.

Differential phase distortion rotates the affected phasors individually with respect to the axes. The amount of rotation depends upon the amount of this distortion, which in turn depends on their individual luminance levels.

6.2 MODIFICATIONS REQUIRED FOR THE PAL CODER

Taking magenta as an example, the PAL system transfers the magenta phasor from the first quadrant to the fourth quadrant on alternate lines. It achieves this by reversing the polarity of the V chrominance signal (i.e. equivalent to a 180°V phase shift). The magenta signal originally had values of U = 0.29 and V = 0.52, so its phasor could be represented in j notation as M = 0.29 + j 0.52. On alternate lines, the coder converts this to M = 0.29 − j 0.52 so that it lies in the fourth quadrant.

Given that the polar representation of a magenta phasor is M = 0.59 /60°, what will be the polar representation for the corresponding phasor on the alternate lines? M = ·59∠-60°

The switching of the V signal polarity is achieved in a PAL coder by a 0/180° switch. The switching is initiated by a V Axis Switch (V.A.S.) waveform.

V-Axis Switch (V.A.S.)

This waveform may either be supplied from the same sync pulse generator as the mixed-sync signal or, in later coders, derived from the incoming mixed-sync and burst-gate waveforms. The VAS waveform is a half-line-frequency square wave timed coincident with the leading edge of the line-sync component of mixed-syncs.

Blue

If the output of a PAL Coder was fed into an NTSC decoder, what colour would magenta be reproduced as? What modification do you think is required to an NTSC decoder to convert it into a PAL decoder? V axis must be matched.

Before considering a PAL decoder, a further modification to the coder must be considered. The PAL decoder requires information to enable it to detect which type of line it is to decode, i.e. does it have to switch the V axis or not. This information is conveyed by the colour burst.

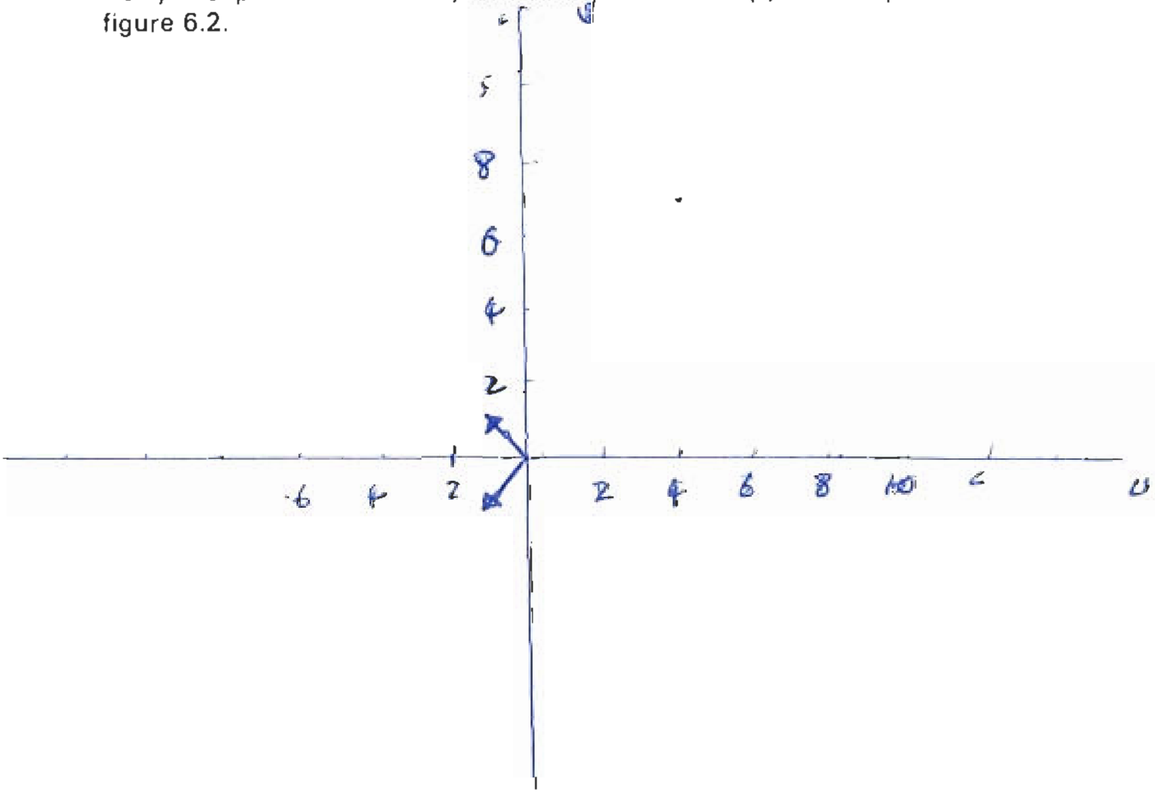
The burst in the PAL system has equal amplitude U and V components. As the V component is influenced by the V-axis switching, the burst phase alternates between 135° and 225° relative to the + U axis.

(a) *If the phasor representation of the unswitched colour burst in the PAL system is CB = (−0.15 ÷ √2) + (j0.15 ÷ √2) volts what are the polar values of the colour burst vector.* ·158 ∠135° (-·106 + ·106)
  (i) *on a normal line, and*
  (ii) *on a line with the V axis switched by 180°* ·158 ∠225° (-·106 - ·106)

  Draw these two values on a phasor diagram, together with the two phasors produced by magenta having components of U = 0.41 volts and V = 0.72 volts.

(b) *What is the peak-to-peak value of the colour burst?* ·3V

Ask you supervisor to check your answer and then copy the four phasors onto figure 6.2.



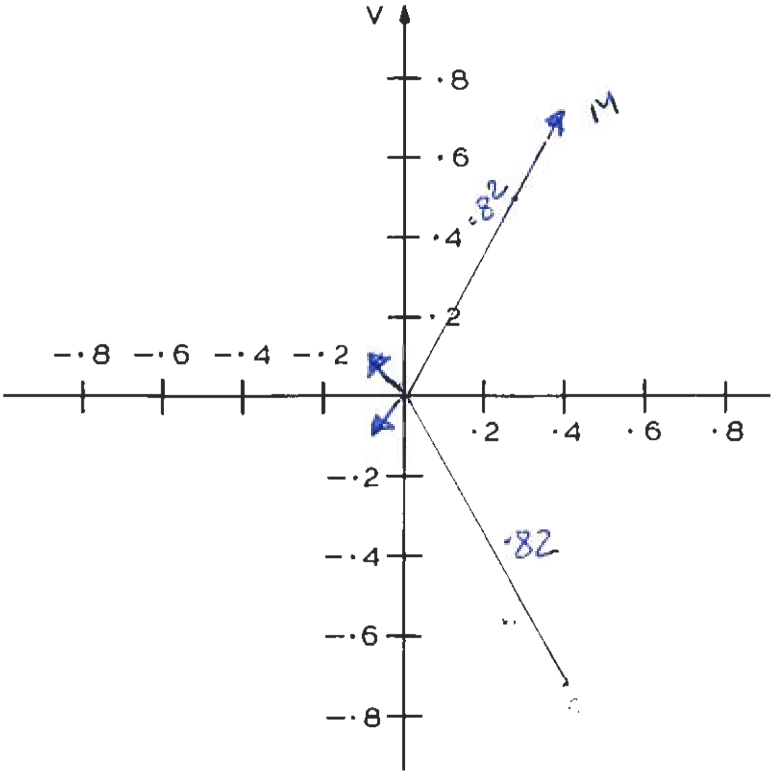


Figure 6.2 The PAL Colour Burst

6.3 PAL CODER BLOCK DIAGRAM

PAL Coder

The extra features required in a PAL CODER can now be added to the block diagram of Figure 3.7. The modifications requried for the PAL system coders are:-

(a) addition of the 0/180° PAL switch fed with the VAS waveform.

(b) modification to the signal to generate the burst at 135° relative to the U axis.

A typical block diagram of a PAL coder is shown in Figure 6.3; and Figure 6.4 shows the waveforms to be found throughout the coder.

[The (G – Y) waveform is included for reference purpose, although this waveform is only found in the decoder.]

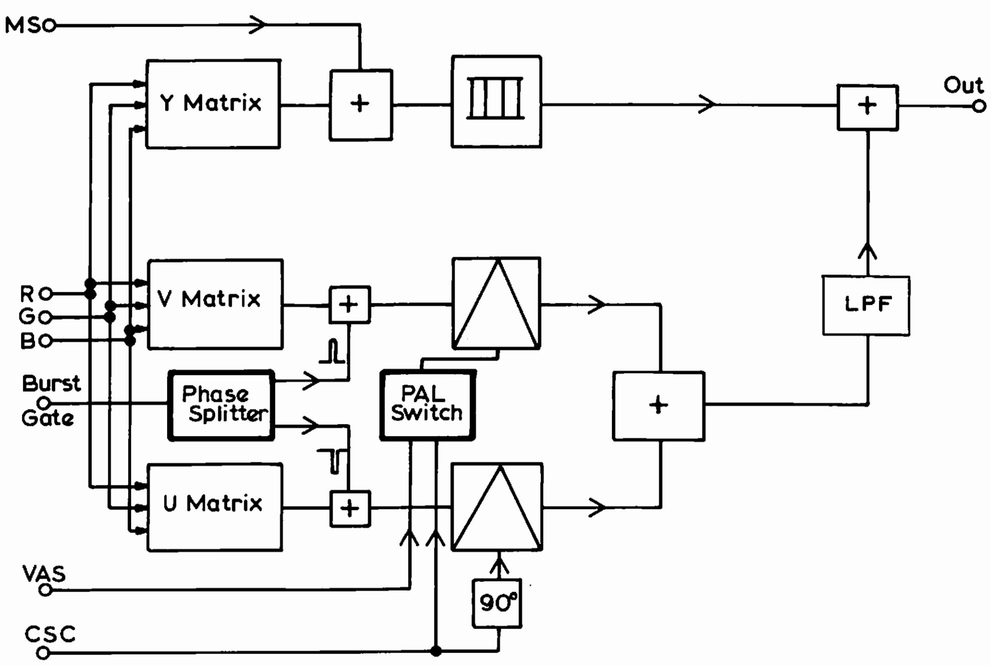
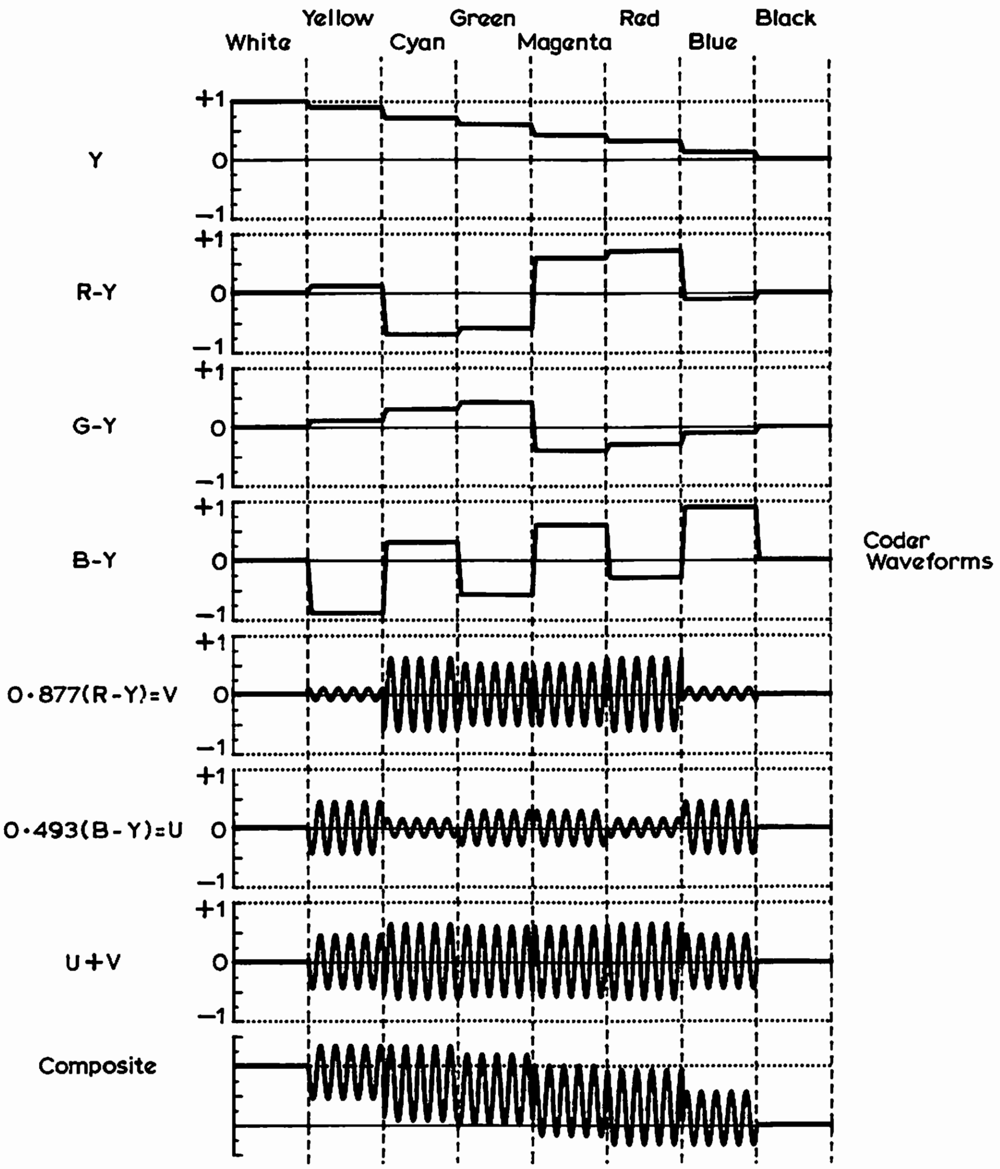


Figure 6.3. PAL Coder Block Diagram



Coder Waveforms

Figure 6.4 Theoretical Waveforms for a Set of Colour Bars

6.4 MODIFICATIONS REQUIRED FOR A PAL DECODER

You have already identified the requirement of a PAL decoder to restore the switched V axis to normal. To enable it to do this, it utilises the VAS information contained within the colour burst.

In a decoder the output of the B.L.O. has its phase compared with that of the burst on each line. The error signal which results is used to lock the phase of the oscillator to that of the incoming burst. What sort of error signal would you expect from a PAL colour burst?

VAS

The decoder B.L.O. must lock to the mean phase of the burst. The error signal produced by the phase comparator must be averaged over many lines. This is achieved by feeding the error signal into a long time constant C.R. circuit (viz: an integrating circuit). Having locked the B.L.O. to the mean phase of the burst, comparison can now take place on a line-by-line basis e.g. using the unsmoothed error signal. This consists of alternating positive and negative errors. The specification of the VAS waveform is that it is timed coincident with the leading edge of line-sync pulses. This can be achieved in the PAL decoder by using the error signal produced by comparing the phase of the burst with its mean phase, to steer a bistable which is clocked by line-sync leading edges.

A block diagram for this part of a PAL decoder is shown in figure 6.5

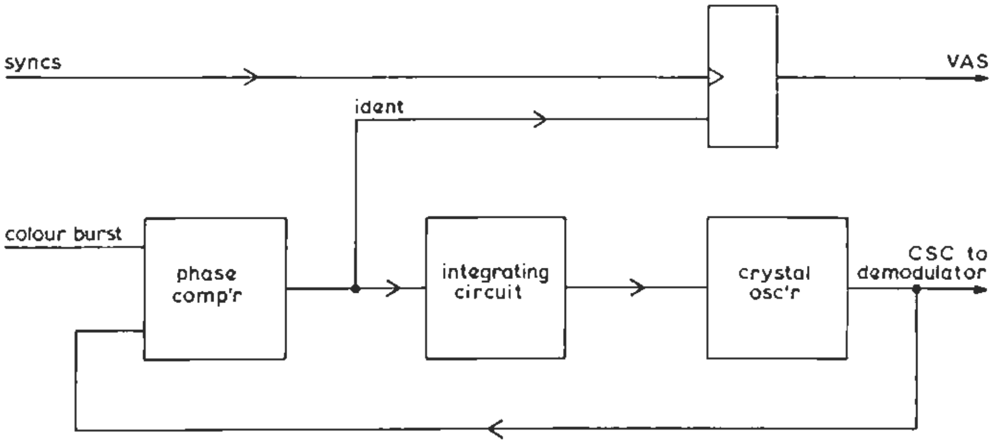
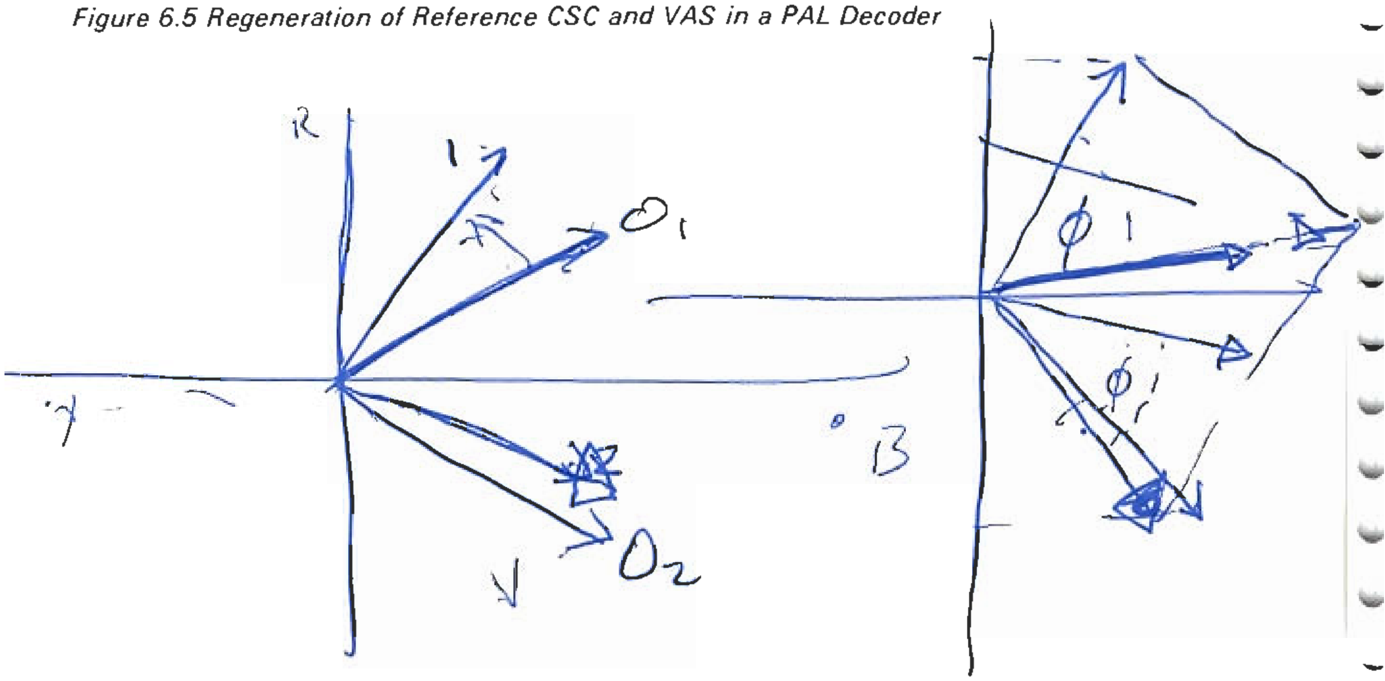


Figure 6.5 Regeneration of Reference CSC and VAS in a PAL Decoder



6.5 THE PAL FOUR-FIELD SEQUENCE

In the first package of this module, you encountered the two fields which together make one picture. The start of field one was defined as the point when the line-sync reference and the field-sync reference (leading edge of the first broad pulse) were coincident. This occurs every two fields or every 625 lines. With PAL signals the VAS waveform is at half-line frequency. This means that if the VAS waveform is positive-going at the start of a certain field, two fields or 625 lines later it will be negative-going. It therefore takes four fields before the same relationship between line-sync, field-sync and VAS repeats itself.

The PAL television signal therefore has a FOUR-FIELD SEQUENCE.

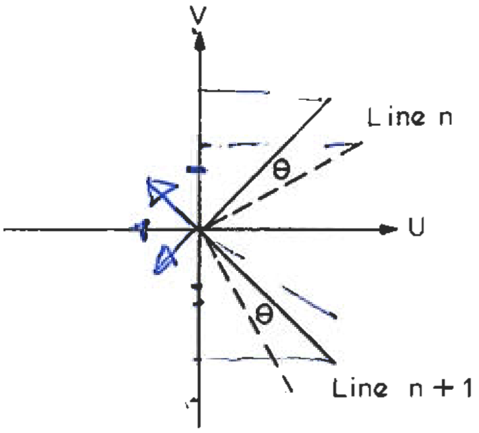
Four-field Sequence

(This excludes consideration of the colour subcarrier to line sync relationship which will be considered later.)

6.6 PHASE ERRORS WITH PAL

We are now in a position to examine how phase errors in the PAL system affect the displayed picture. The effect is best considered by analysing the changes to the chrominance phasors.

A phase error rotates the chrominance phasors by some fixed angle, θ. Considering magenta again, the effect of $\theta°$ of phase error is shown in figure 6.6.



MR

MB

Figure 6.6 Effect of A Phase Error on a Magenta Colour

Describe the effect you would expect to see with the PAL system on a displayed Magenta if 24° of phase error was present. If you are in the slightest doubt about your answer to this question, sketch a phasor diagram for magenta showing the normal and distorted phasors, then add to your diagram the resulting phasor after the demodulator V-axis switch operation has taken place.

The question you have just attempted asked for the effect on a displayed picture. Check your answer by turning to the Practical Unit and undertaking demonstrations 6.1 and 6.2.

6.7 HANOVER BARS

The effect of a burst-to-chroma phase error on, say, magenta results in too much V and too little U on one line, (Reddish Magenta) and too little V, too much U on the next, (Bluish Magenta). The eye would be quite capable of averaging this hue difference if it were not for the fact that the colour difference signals also carry brightness information. The brightness difference is not averaged by the eye and when the fact that interlace, which results in adjacent pairs of lines, is taken into account, the effect is most noticeable to the viewer. This variation on alternate pairs of lines is known as HANOVER BARS. (or Venetian Blinding).

Hanover Bars

The problem is due to the phase error which results in the demodulators switching over an incorrectly phased half-cycle period of the input signal. This causes crosstalk of the U into V, and V into U signals respectively. The system would be improved if the chrominance signal could be separated into its U and V components before demodulation.

6.8 THE DELAY LINE PAL DECODER PRINCIPLE

The separation into U and V signals is achieved by means of a one-line delay as shown in figure 6.7.

Delay PAL

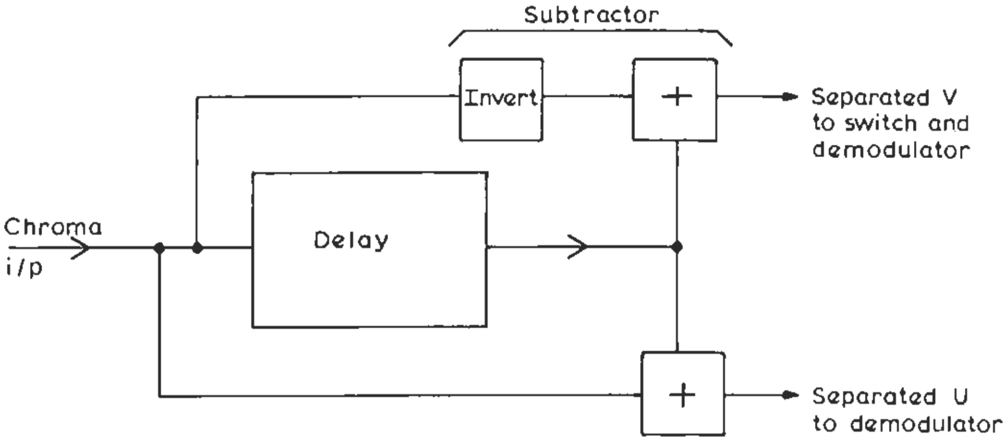

Subtractor
Invert
+
Separated V to switch and demodulator
Chroma i/p
Delay
+
Separated U to demodulator

Figure 6.7 Operation of a Delay Line Decoder

Consider an undistorted magenta chrominance vector on line n as being M(n) = U + jV.

On line n + 1, the vector will be M(n + 1) = U −jV.

If the signal on line n is delayed by one line and then added to the signal on line n + 1, the result will be:

$$M(n) + M(n+1) = U + jV + U - jV$$
$$= 2U.$$

If the output of this adder is now halved, the original U component is isolated and can be fed to the U demodulator for conversion into the (B − Y) colour difference signal.

Deduce the output produced by subtracting the chrominance signal on line (n + 1) from that on line n, i.e. M(n) − M(n + 1) = ?

$$= U + jV - (U - jV)$$
$$= +2V$$

The delay line can be regarded as part of a filter which separates line-rate coherent U information from half-line-rate coherent V information. It happens to average two lines in so doing. Therefore a sine wave of V chroma with no U results from one output and a sine wave of U chroma with no V from the other. There can be no crosstalk between the U and V signals in the demodulators and hence no hanover bars. This is shown in figure 6.8.

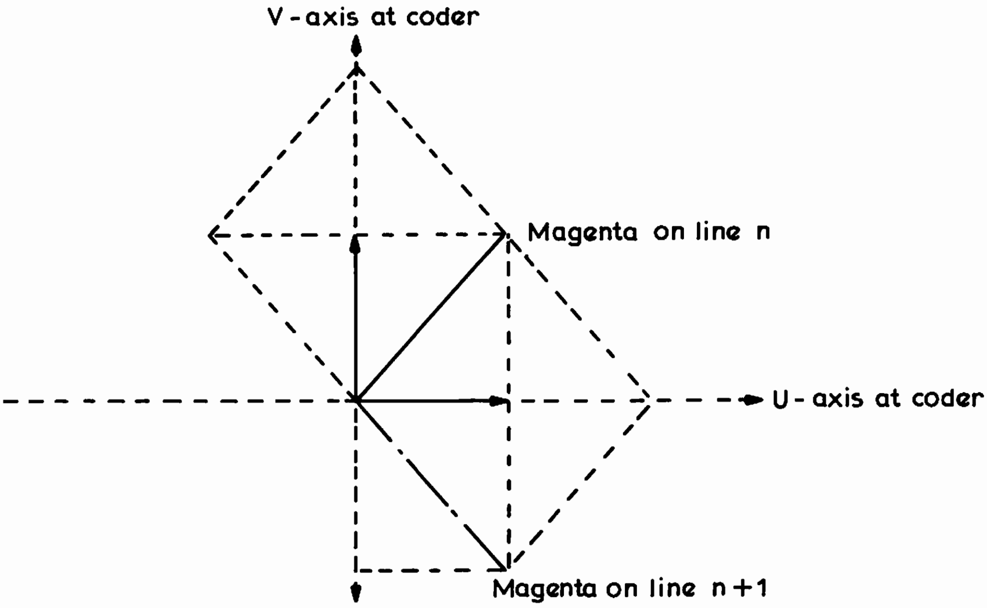


Figure 6.8 Separation of U & V components by means of a 1 line delay

This method of decoding using a delay line is often referred to as PAL-D to distinguish it from simple PAL, PAL-S.

6.9 THE EFFECTS OF PHASE ERRORS ON THE DELAY PAL DECODER

It should be apparent from figure 6.8 that the outputs of the delay line stage are U and V signals of constant amplitude, irrespective of which type of PAL line is being transmitted. The phase of these two signals are mutually at 90° and correspond to the original U and V axis at the coder. If there is no phase error in the system then the demodulator phases in the decoder will match *exactly* the original U and V axes. Under such conditions the demodulator outputs will be the original U and V signals.

Note: The one line of delay produced by the delay line must be an integral number of cycles of subcarrier, and not 64.00 microseconds. If this is not so, a phase error which is independent of the input signal will be introduced. This results in reduced colour difference signal outputs, crosstalk between U and V and hence Hanover bars.

What if there is a phase error however?

Take the case where, due to a fault, the burst locked oscillator locks up 20° out of phase with the reference burst. In this example the demodulating axes no longer match those present in the coder. However, they will still be at 90° to each other, as shown in figure 6.9.

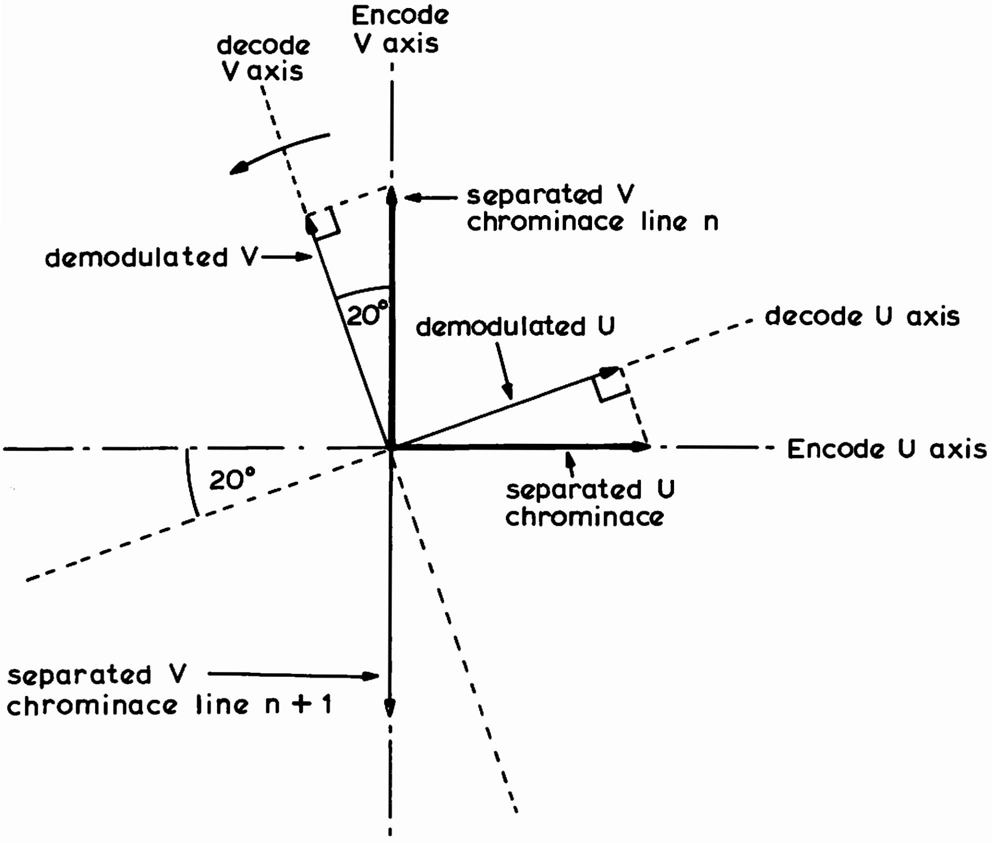


Figure 6.9 Effect of a phase error on the demodulator outputs after delay line separation

The effect of demodulating off-axis is to reduce the amplitude of the demodulator output. The demodulator output is equal to that component of its input which is in phase with its reference. In fact the output is given by:

Demodulator O/P = Demodulator I/P × Cos (phase error)

As the phase error is a constant and the demodulator input is also a constant there will be no change in the demodulator output on a line-by-line basis. As a result the display is free from Hanover Bars.

The same degradation applies to both the U and V signals, i.e. both are reduced by the same factor of Cos (phase error). This means that their *relative* amplitudes are unchanged so there is no change in the hue of the picture displayed. As their amplitudes have decreased, however, there will be a change in the saturation of the display and, when the non-linearity of the picture tube is taken into account, a change in brightness as well. For small phase errors the brightness change is often the most perceptible effect of the phase error.

6.10 PAL DECODER BLOCK DIAGRAM

PAL Decoder

The extra features required in a PAL DECODER can now be added to the block diagram of figure 3.8. The modifications required for the PAL system are,

(a) B.L.O. locked to mean phase of the burst using a long time constant on the error signal.

(b) V.A.S. waveform produced using a short time constant on the burst error signal.

(c) The V component switched by 180° on alternate lines using regenerated V.A.S. waveform. (Alternatively the phase of the V modulator reference signal may be switched by 180°).

(d) The inclusion of a delay line stage which in a broadcast monitoring situation may be switched out. (if a PAL-D decoder is operated in the SIMPLE Mode, the gain of the undelayed chrominance signal must be increased by 6dB to compensate for the absence of signal from the delay line stage).

(e) Provision of a colour killer. (The presence of the V.A.S. waveform may be used as an indication of the presence of a burst. The V.A.S. waveform can be rectified and used to enable the chrominance information. In the absence of burst decoding is inhibited, thus avoiding any high-frequency luminance components of the monochrome signal being decoded as colour).

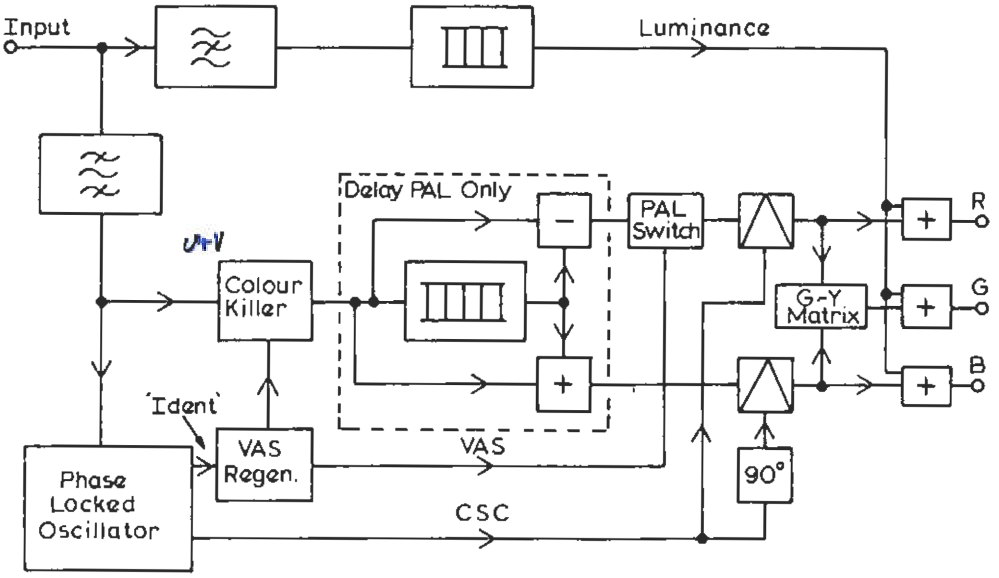


Figure 6.10 PAL Decoder Block Diagram

To verify the effects on a picture of phase distortion when decoded using a delay line decoder, turn to the practical unit and undertake demonstrations 6.3 and 6.4.

6.11 TABLE SHOWING THE EFFECTS OF PHASE AND AMPLITUDE VARIATION OF THE CHROMINANCE SIGNAL

MODE	AMPLITUDE VARIATION	PHASE VARIATION W.R.T. BURST
NTSC	SATURATION & BRIGHTNESS ERRORS	HUE, SATURATION & BRIGHTNESS ERRORS
SIMPLE PAL	SATURATION & BRIGHTNESS ERRORS	HANOVER BARS
DELAY PAL	SATURATION & BRIGHTNESS ERRORS	SATURATION & BRIGHTNESS ERRORS ONLY
		COMPLEMENTARY COLOURS IF ERROR >90° <270°

COMPARISON
OF
PERFORMANCE

6.12 INVESTIGATION OF SUBCARRIER-BASED SYSTEMS

Finally, before completing this passage, carry out demonstrations 6.5 and 6.6. These investigate some of the problems associated with the use of subcarrier-based systems.

SUMMARY

The first part of this summary covers material dealt with in Volume 2 of the Television Principles Module. It is included here for completeness in summarising the overall coding and decoding process.

Colour Television Principles (from Volume 2)

A colour signal originates as red (R), green (G) and blue (B) component picture signals, together with synchronising information for the display scans. The transmitted signal should occupy no more bandwidth than a monochrome (brightness only) signal and give compatible pictures with a monochrome display.

Colour coding is the method used to combine the R, G, B and sync components into one signal for distribution and transmission to the viewers.

Colour decoding recovers the original R, G, B and sync signals to feed the colour display.

The R, G and B signals from the camera are matrixed to form a luminance (Y) signal and two colour difference (R – Y and B – Y) signals. The Y signal alone can be used to drive a monochrome display. It can also be used, in combination with the transmitted R – Y and B – Y signals, to recover the original R, G and B colour information.

There is a limitation on the usefulness of the Y signal for a monochrome display. The proportions of 0.3R + 0.59G + 0.11 B which make up the Y signal give the correct relative brightness for all colours only if the R, G and B signals are linearly proportional to the amounts of red, green and blue light in the original scene. In a practical camera the coder is fed with R, G and B signals which have been pre-corrected for the gamma characteristic of the display tube and are no longer linearly proportional to the light content of the scene.

The resultant Y signal is always too small in any highly coloured area to give a true representation of its brightness. The monochrome display makes these colours appear darker relative to white or grey objects than they would appear to an observer alongside the camera.

The decoding process produces R, G and B signal amplitudes which are identical to the camera outputs, and so no brightness is lost on the colour display. Thus R, G and B signals carry brightness, as well as 'colouredness', information, because the coding and decoding processes take place on signals which are not linearly related to the red, green and blue content of the original scene.

Modulation Systems to carry R - Y and B - Y

Suppressed carrier amplitude modulation is used to carry colour difference signals in both the NTSC and PAL colour television systems.

For each modulator the modulated carrier output amplitude is proportional to the modulating signal amplitude. The output carrier polarity, relative to unmodulated carrier, is dependent on the input signal polarity.

The modulated signal must be demodulated with an identical phase of demodulating carrier to recover the polarity and amplitude information intact. As the carrier phase for the demodulator is varied, the output falls until at 90° there is no output. Continued phase shift towards 180° causes the signal to emerge with the opposite polarity.

In the PAL system two modulators are fed with carriers which are at 90° with respect to each other and the modulator outputs are combined. The separate channels of information are recovered by two demodulators, also fed with carriers at 90°.

The carrier is not sent continuously. A stable crystal-controlled oscillator is used at the decoder and phase-locked once per line to a short burst of carrier from the modulators in the coder. The burst of 10 (±1) cycles is sent during the back porch of line blanking.

The Colour Video Signal

The coder output contains luminance (Y), chrominance (modulated R – Y and B – Y) and synchronising signals. The largest amplitude of the chrominance signal occurs during the transmission of 100% amplitude, fully saturated primary colours; i.e. red, green and blue, and their complementary secondary colours; cyan, magenta and yellow.

Weighting is applied to the R – Y and B – Y signals to attenuate them so that the peak-to-peak chrominance signal amplitude is not unacceptably large with respect to the luminance signal.

R – Y weighted by a factor of 0.877 becomes V
B – Y weighted by a factor of 0.493 becomes U

The U and V signals are the ones applied to the modulators.

Colour Bars

100% colour bars (i.e. full amplitude, full saturation, colours in descending luminance order) provide the most stringent test waveform for the coding/decoding process.

95% colour bars are desaturated so that the chrominance signal amplitude is reduced. These bars are suitable for use in the distribution and transmission chains, where day-to-day drifts in gain might cause an overload to occur with the larger 100% bars.

EBU bars have the advantage of using 75% amplitude for the colour bars so that the tips of the chrominance components do not exceed white level. The whole signal is within the 1 volt peak-to-peak range of a monochrome signal.

Phasor Displays

A phasor plot of decoded V along the vertical axis and decoded U along the horizontal axis can be used to display the amplitude and phase relationships of the chrominance signal. Any point on the plot can be described by its amplitude (length from centre) and phase angle relative to the horizontal axis. By resolving onto the axes, the relative proportions of V and U in the chrominance signal can be found. The phase of the plot relative to these axes determines the hue, the amplitude determines the saturation, and hence brightness, of the colour.

System Comparison: NTSC v PAL

The simpler NTSC system contains no protection against errors in transmission which may cause the decoding carriers to be incorrectly phased to the encoding carriers. Such an error could be due to an incorrectly phased burst-locked oscillator, incorrect burst phase or a differential phase error. In the latter instance, the error varies as a function of luminance level.

Whatever the source of a phase error its effect is the same. The colour is demodulated to incorrect proportions of U and V. Because nothing is done to counteract phase errors in the NTSC system, the colours are reproduced with the wrong hue. If the resulting R, G and B signals are carefully examined, it will be found that a change in saturation and intensity has also occurred.

The PAL system attempts to overcome the effects of phase errors by arranging that they cancel out over a two-line period. In the coder the polarity of the V-axis is reversed on alternate lines. A similar reversal in the decoder restores the correct polarity prior to demodulation.

To enable this to take place the PAL colour burst differs from its NTSC counter-part by having a V component. The burst phase consequently alternates in phase about the –U-axis. Circuitry associated with the burst-locked oscillator detects the swing and ensures correct V-axis polarity in the decoder.

In a Simple PAL (PAL-S) decoder the attempt to cancel out the effects of a phase error takes place after the colours have been displayed. Because the eye does not resolve colour in fine detail it is not able to distinguish between the lines having one error and those with the opposite polarity error. Unfortunately, interlace results in pairs of lines of one hue followed by pairs of lines of another hue. Additionally, there is a brightness difference between the pairs of lines. These effects result in a much greater visibility of the pairs of lines, which are known as Hanover Bars.

The problem described above is eliminated in a Delay PAL (PAL-D) decoder. A one-line delay is used to make signals from two successive lines available to the demodulator. These signals are then combined in a way which separates the U and V components. By doing this any crosstalk between the U and V signals is elminated, consequently phase errors cannot change the relative proportions of the demodulated U and V signals. Thus there can be no error in the displayed hue, (Note that for errors of more than 90° the displayed hue will be complementary to the original hue.)

Phase errors now give a reduction in amplitude of the demodulated colour difference signals, with a corresponding change in display saturation and, due to the non-linearity of the system, a change in display brightness.

Note that, due to the V-axis switching, a PAL signal only repeats itself over a four-field period.

The SECAM System

The SECAM system uses frequency modulation to convey chrominance information and is largely immune to phase and amplitude variations of the chrominance channel.

The channel is time-shared between the R-Y and B-Y signals, the appropriate components being selected by electronic switches in the coder and decoder. To make both chrominance components available to the demodulators, a one-line delay is included in the decoder.

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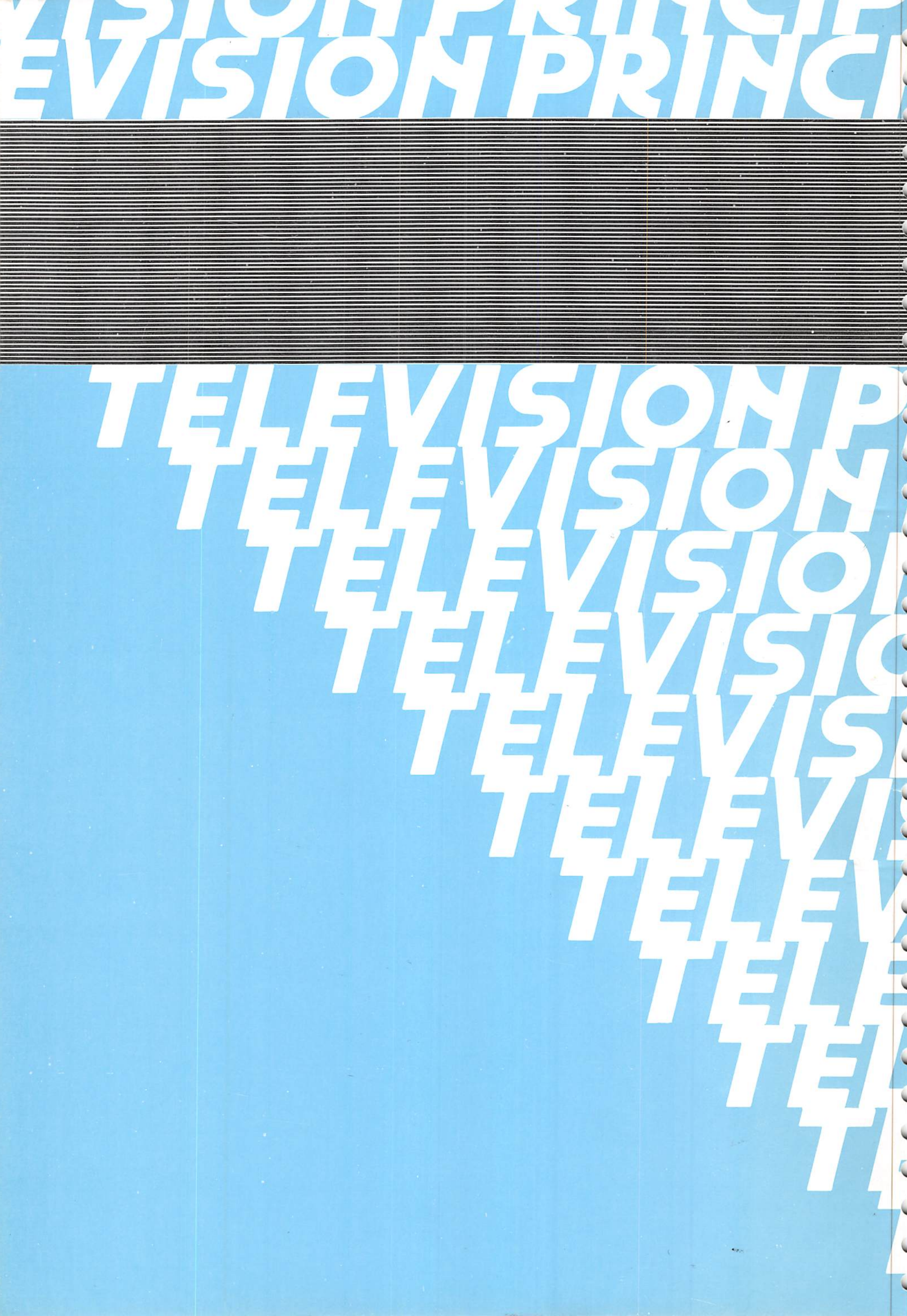

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